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**Wrong-
way
wings**
give new agility to
supersonic planes



Wrong-way wings

aid maneuverability of supersonic planes

New materials are putting new life in an old concept: forward-swept wings

By BEN KOCIVAR

BETHPAGE, N.Y.

At Grumman Aerospace Corporation's sprawling plant on Long Island,

I stood inside the low-speed wind tunnel looking at what seemed to be a flying aberration: a model airplane with its wings stuck on backward.

The seven-foot wings of the radio-controlled balsa model were swept sharply forward, like the outstretched arms of Superman. The plane appeared designed to fly in reverse. For free-flight tests, a 2½-hp glow-plug

model-plane engine in its fuselage drives a ducted propeller that shoves air out the tail much like a jet engine—and shoves the plane in the conventional direction. This is no supersonic machine, of course, but if its strange forward-swept wings live up to their promise, the little model may forecast a new generation of high-

Continued



Forward-swept-wing design proposed by General Dynamics would use existing fuselage, elevator, rudder, and engine of

new F-16 fighter, already in production, and attach forward-swept wings in place of aft-swept wings. Such an approach

could quickly provide a manned flying test-bed to give data that could help determine design of composite wing.



Rockwell's full-scale Styrofoam mock-up author Kocivar saw at Paris Air Show looks very real. Large aft-swept canard

shares weight with forward-swept main wing and provides some trim control, but Rockwell design gets most longitudinal

control from trailing edge of main wing, which has ailerons outboard and elevons inboard. Canard moves as a unit.



Balsa-wood, radio-controlled model (above) of the Grumman design (see cover) was built as an inexpensive test vehicle to prove the computer program used to design the forward-swept wing and canard. The flying model tested the longitudinal stability of the design at about 1/100 the cost of a tunnel test program. The model could be made to stall, but refused to spin. Later, a model underwent supersonic wind-tunnel tests (up to Mach 1.5). Right: Col. Norris J. Krone Jr., manager of DARPA's forward-swept-wing program, displays planforms of the three models at his Arlington, Va., office. While some aerodynamic benefits of the concept were long known, Krone's study of advanced composite structures convinced the Air Force and NASA that a forward-swept wing could be made lightweight enough to capitalize on those benefits at transonic speeds (600-1000 mph).





Junkers JU-287 four-engine jet bomber (drawing above), flown by Germans in 1944, had 15-degree forward wing sweep, conventional tail, and jet engines mounted under wings and along fuselage. The forward-swept wings provided good control at low speeds, and their placement allowed more room in the fuselage. At top: Inside Grumman's wind tunnel, Glenn Spacht (left), deputy director, and Robert Roemer (center), program director, explain the working controls of the radio-controlled model to author Kocivar. Its wings have a 30-degree sweep.

speed, high-performance aircraft.

Robert Roemer, Grumman's forward-swept-wing program manager, and Glenn Spacht, his deputy, summarized the prime merits of the design: greater maneuverability and control—essential characteristics for many of tomorrow's military and even civilian planes.

Currently, forward-swept-wing research is aimed at designing an improved fighter plane. The program is directed by the Defense Advanced Research Projects Agency (DARPA), a special unit of the Department of Defense chartered to develop high-risk technologies with potentially high benefits. On forward sweep, DARPA, with the assistance of the Air Force and NASA, is sponsoring design work and testing by three aircraft companies: Grumman, Rockwell International, and General Dynamics.

Advantages of forward sweep

Tomorrow's fighter planes may need more than speed. They may need agility for close air-to-air combat and to dippy-doodle out of the path of anti-aircraft missiles they spot. Agility

A forward-swept-wing fighter could weigh 20

and aerodynamic control will be required so that pilots can dip and slip among the rocks and rills to elude enemy radar. Speed alone, then, does not make the forward-swept wing a look of the future. A combination of speed, agility, and low-speed flying qualities does.

Col. Norris Krone, a veteran Air Force pilot, leads the DARPA program on forward sweep. He became intrigued with the concept while working on a Ph.D. thesis in aeronautical engineering at the University of Maryland in 1972. I talked to him in his Arlington, Va., office.

"The models, wind-tunnel tests, and computer analysis we are supporting will let us design a demonstrator aircraft with confidence. We may get to a man-carrying version as early as 1982," he told me. About \$4 million has gone into research so far. A pilot-rated demonstrator could cost \$40 to \$100 million more.

If the military program is successful, the forward-swept wing could also change the look of private planes and airliners. Such planes would have greater range, slower stall speeds, spin resistance, slow-speed control for easier landings and takeoffs, and, because of design geometry, more cabin space.

Why it's better

What makes the forward sweep intrinsically better? "Sweeping a wing" Glenn Spacht explains, "reduces the shock wave—the cause of drag (low performance)—as the plane approaches the speed of sound. In comparing wings with the same 45-degree sweep—one forward, the other back—tests reveal that the shock from the forward-swept wing is more highly angled and therefore weaker than the one on the aft-swept wing (see diagram). That spells less drag and greater maneuverability, especially in the critical transonic region, from 600 to 1000 mph."

Spacht also explained why the forward-swept wing gives better stall characteristics and more lateral control at slow speeds. "On conventional straight wings," he said, "the wingtips are designed with a built-in downward twist. This gives them a lower angle of attack than the root of the wing, which helps maintain lateral control because it makes the center of the wing stall and lose lift before the wingtip. So while the plane may dip down, it does not roll. The disadvantage is that this wing twist increases the aerodynamic drag at cruise and high speeds, limiting speed and range.

"The problem is increased in an aft-swept wing. The air hits the wing at the root first. Air starts moving up even before the wind actually hits the wing. Since the tips are farther back, the apparent wind is already moving upward when it reaches the wingtip. This increases the angle of attack there, and the wingtip stalls earlier than the root, causing abrupt loss of lift and a sudden pitch up. The plane may even roll out of control.

"With the forward-swept wing, the wingtip is ahead. It is the root that has the higher induced angle of attack and would tend to stall first. That would also mean a sharp pitch up, since lift would be lost at the rear of the plane. To avoid this, a slight upward tilt is built into the wingtips. This tends to distribute lift equally over the entire wing. The result is better lateral control, because the plane simply drops down straight ahead, builds up speed, and regains lift. And because the wingtip is only very slightly twisted, the plane suffers little drag penalty at high speeds."

Old concept in new clothing

The idea of using forward-swept wings goes back to World War II. In 1944 the Germans built and tested a Junkers JU-287 four-engine jet bomber (see diagram) with a forward sweep of 15 degrees. The wings were attached at the rear of the plane, which left more room inside. The increased space, not high performance, was the reason for the forward sweep. The test plane was damaged by Allied bombers and later captured by the Russians.

In the '60's, members of the same German design team built the HFB-300 Hansa business jet with similar forward-swept wings. I flew in one of these a few years ago. I have also flown in a Swedish two-seat Saab MF-115 and a German powered glider; both have wings with slight forward sweep. But none of these planes was designed for high speed.

The advantage of forward sweep for transonic and supersonic flight has been known for some time, but until recently, technical problems made such planes impractical. For high-speed flight, the wings must be swept much more than 15 degrees forward. Some designs propose as much as 70 degrees of sweep. Wings with such pronounced forward sweep would encounter terrific stresses in flight.

Here's why: When a plane maneuvers (increases the angle of attack and thus the wing loading), the wing bends (see diagram). On a typical aft-swept wing, the wingtip twists down; that reduces its angle of attack rela-

percent less than one of comparable performance with aft-swept wings

tive to the air flow, and hence reduces the load. But on a forward-swept wing the opposite happens. As the air load increases, and the wing bends, the wingtip bends up more, increasing the angle of attack and load. "It's very similar to what you experience when you stick your hand out your car window at 60 mph," explains Spacht. "If your hand is slightly tilted upward, the wind pushes your arm back. Try that at 300 mph and your whole arm would be ripped off." The same thing can happen with an airplane wing. Aerodynamicists call it aeroelastic structural divergence. Put simply, it means the wing breaks.

"So we must make the forward-swept wing stronger," explains Col. Krone. "We can do this with metal, but it adds so much weight that it overcomes the advantage of having the forward sweep."

Composites

"But there are answers to the dilemma," continues Krone. They begin not with aerodynamics, but with those new aerospace materials, the composites (see "Super-Strong Graphite," PS, Apr. '75). It was Col. Krone's thesis on the ability of composites to resist divergence that revived interest in forward-swept wings for high-speed craft. Composite materials such as boron fiber and graphite in a plastic matrix can make a nonmetallic wing a good 30 percent lighter than a wing of the same strength using conventional metal design. Result: The wings can be lighter, stronger, smaller, and cheaper. According to Rockwell, a forward-swept-wing fighter could weigh about 20 percent less on takeoff than one of comparable performance with an aft-swept wing.

Furthermore, engineers can optimize the structure of the wing by varying the orientation and thickness of the carbon plies to help distribute the load properly over the whole wing, thus controlling its twist. They call the process aeroelastic tailoring.

Different design approaches

As the pictures show, the three companies have designed quite different planes for the forward-swept-wing competition. The General Dynamics proposal would modify an existing F-16 by putting on a new wing. This approach has obvious cost advantages for early research of composite wing structures.

Both the Grumman and Rockwell designs, however, go further toward capitalizing on the potential benefits of forward sweep. Grumman's design combines the nose of an F-5 Northrop

fighter with the engine, a GE 404, used in the F-18.

Rockwell, under its former name, North American Aircraft, actually had plans drawn up for a forward-swept-wing version of its famous P-51 Mustang propeller-driven fighter shortly after World War II, but the plane was not built. Rockwell has built a full-scale mock-up of its current proposal (see photo).

Both the Rockwell and Grumman designs use canards, but they are placed differently relative to the wing.

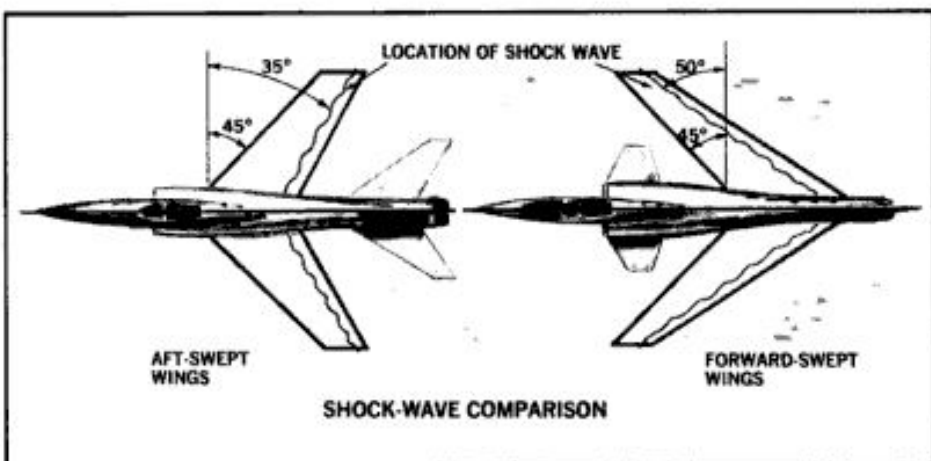
Mike Robinson, Rockwell program

manager, told me the Rockwell concept is derived from its HIMAT (Highly Maneuverable Advanced Technology) plane, an unmanned research plane being developed for NASA. It puts the canard well above the main wing, so that its wake won't interfere with the main wing.

In the Grumman design, the canard and main wing are in line. "Our canard and wing interact to help each other," says Spacht.

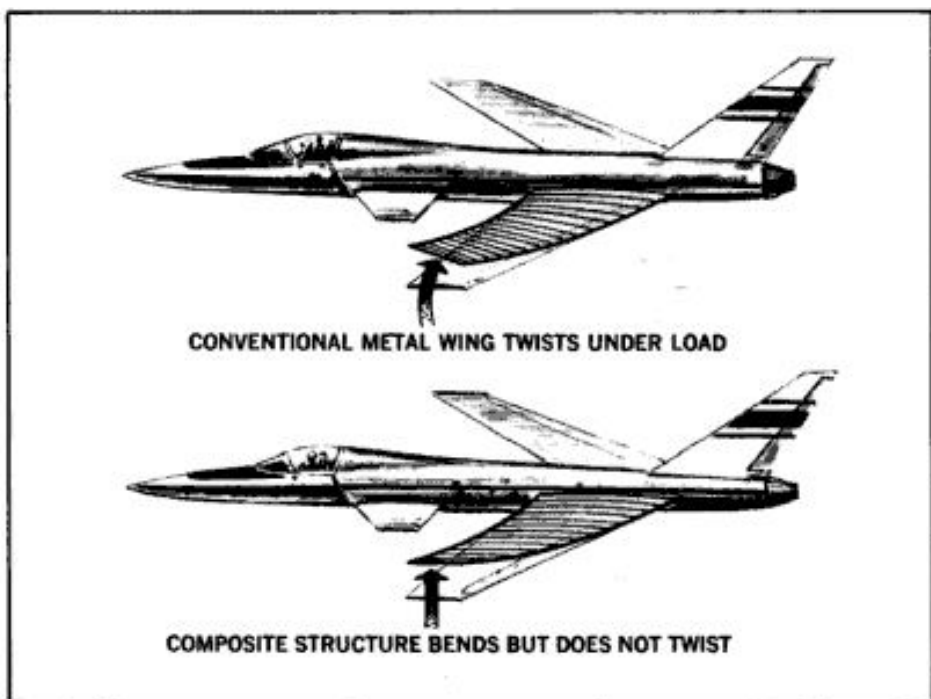
Here's how: When the airplane is pulling up or in a tight turn and thus

(Continued on page 160)



Shock wave on forward-swept wing is weaker than on aft-swept wing of equal sweep. Diagram shows why. Vertical lines represent base from which sweep angles

are measured; wavy lines show position of shock wave. Strength of shock is weaker as its angle is greater; forward sweep creates greater angle, as shown.

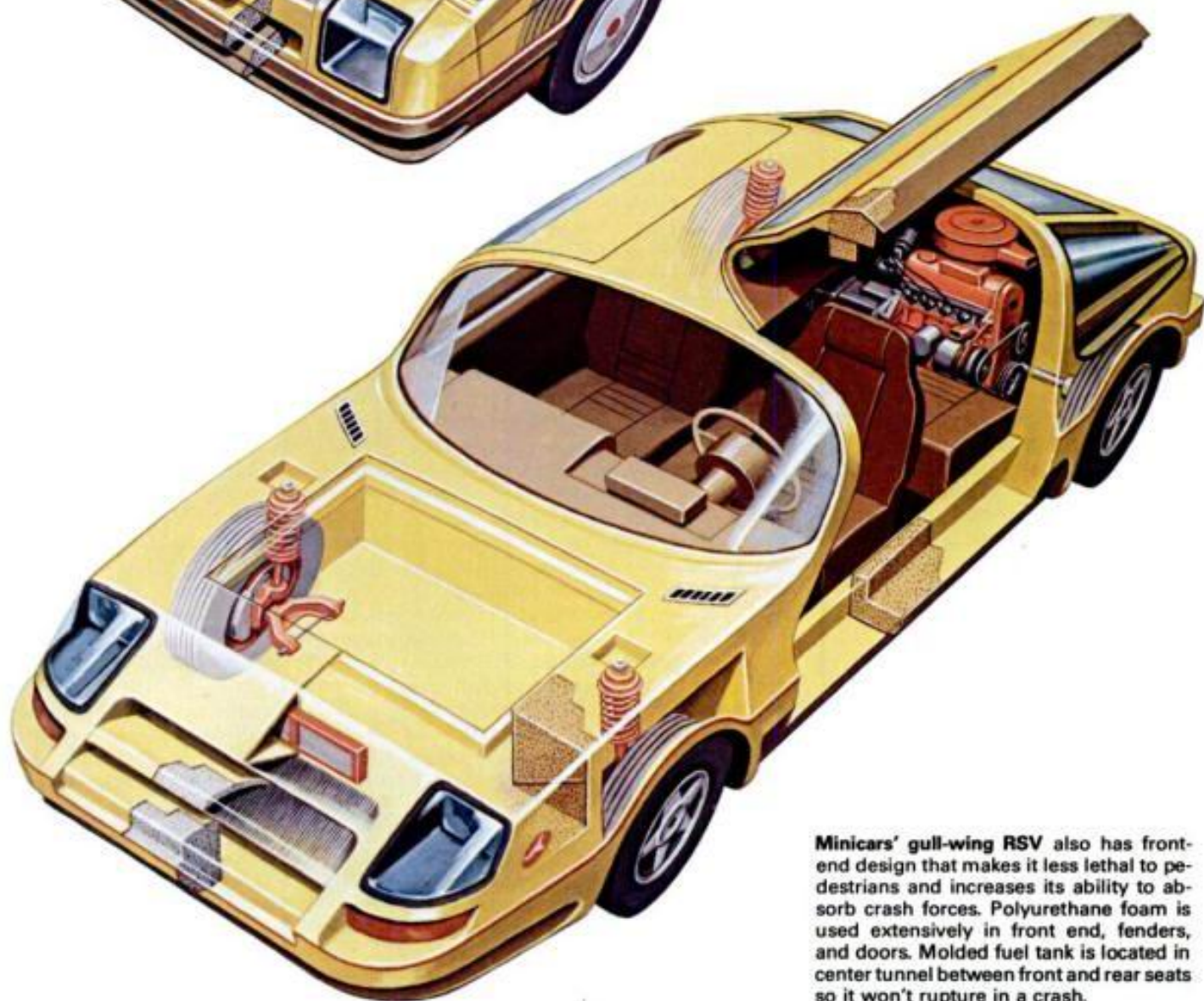
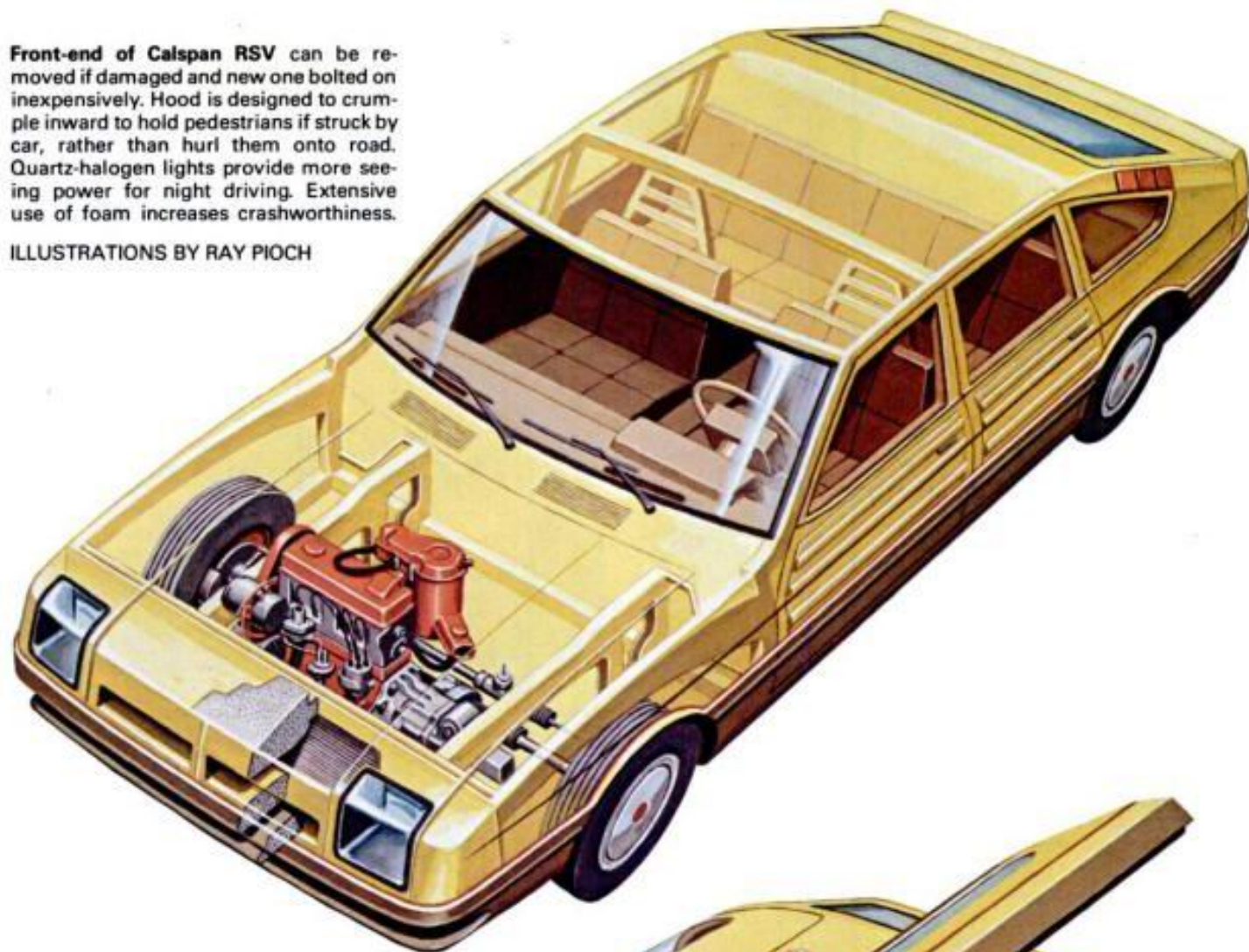


Wingtips twist up (top drawing) when forward-swept-wing planes fly at high speeds or execute extreme fighting maneuvers involving high G-loads. This increases the angle of attack of the wingtips, increasing the load on them, and makes the tips bend up even more. End result

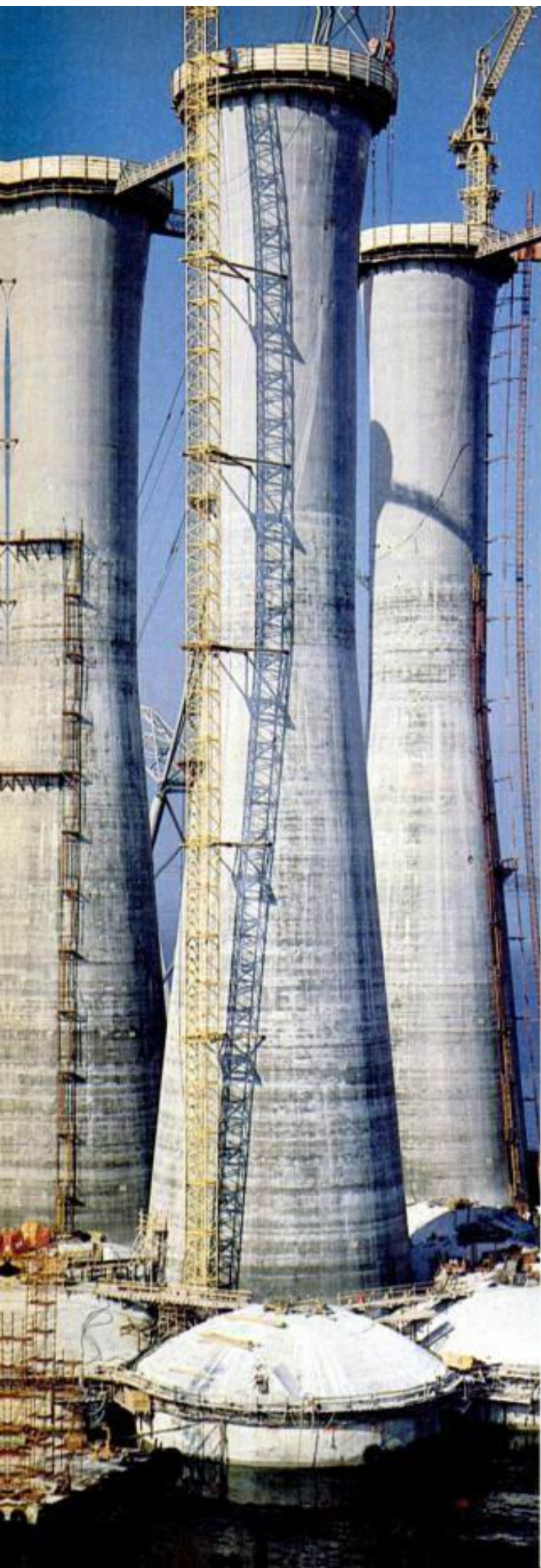
can be wing divergence (failure). By using lightweight composites tailored to spread the G-load properly, the wings can be designed to bend (lower drawing) in order to distribute the load optimally over the entire wing. This keeps wing from twisting, and possible structural divergence.

Front-end of Calspan RSV can be removed if damaged and new one bolted on inexpensively. Hood is designed to crumple inward to hold pedestrians if struck by car, rather than hurl them onto road. Quartz-halogen lights provide more seeing power for night driving. Extensive use of foam increases crashworthiness.

ILLUSTRATIONS BY RAY PIOCH



Minicars' gull-wing RSV also has front-end design that makes it less lethal to pedestrians and increases its ability to absorb crash forces. Polyurethane foam is used extensively in front end, fenders, and doors. Molded fuel tank is located in center tunnel between front and rear seats so it won't rupture in a crash.

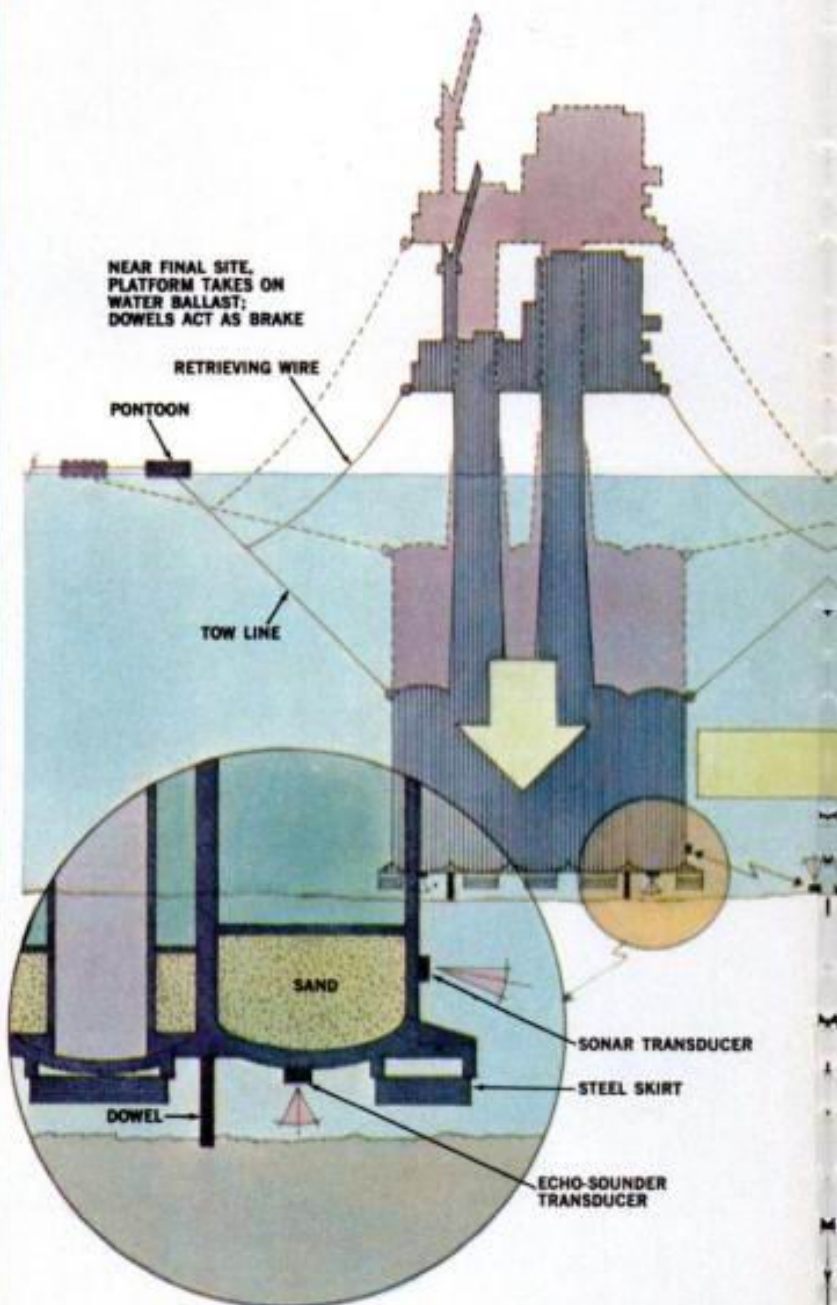


semisubmersible and stabler than a standard drill ship.

So Royal Dutch Shell and Sedco, Inc., a Texas drilling firm, designed a semisubmersible, the Sedco 709, to use the station-keeping thrusters—variable-pitch propellers—already used by drill ships. To hold the rig directly over a drill site, its eight 3000-hp thrusters can be aimed in any direction and set at any speed. They are individually controlled by a Honeywell computer that correlates constantly changing wind, wave, and current data to accurate position information supplied by navigation satellites above and sonic beacons below. Though the 709 is initially towed to the drill site, the thrusters can be used to propel it forward at six knots.

The Sedco 709 can drill in water 6000 feet deep and up to 25,000 feet below the seabed. It can perform in any combination of waves up to 56 feet high, currents of up to 2.4 knots, and winds gusting to 66 knots. In conditions worse than these, the deck becomes too rough for handling equipment, but the vessel can remain on location connected to the subsea well while it waits out the storm. In 40-foot

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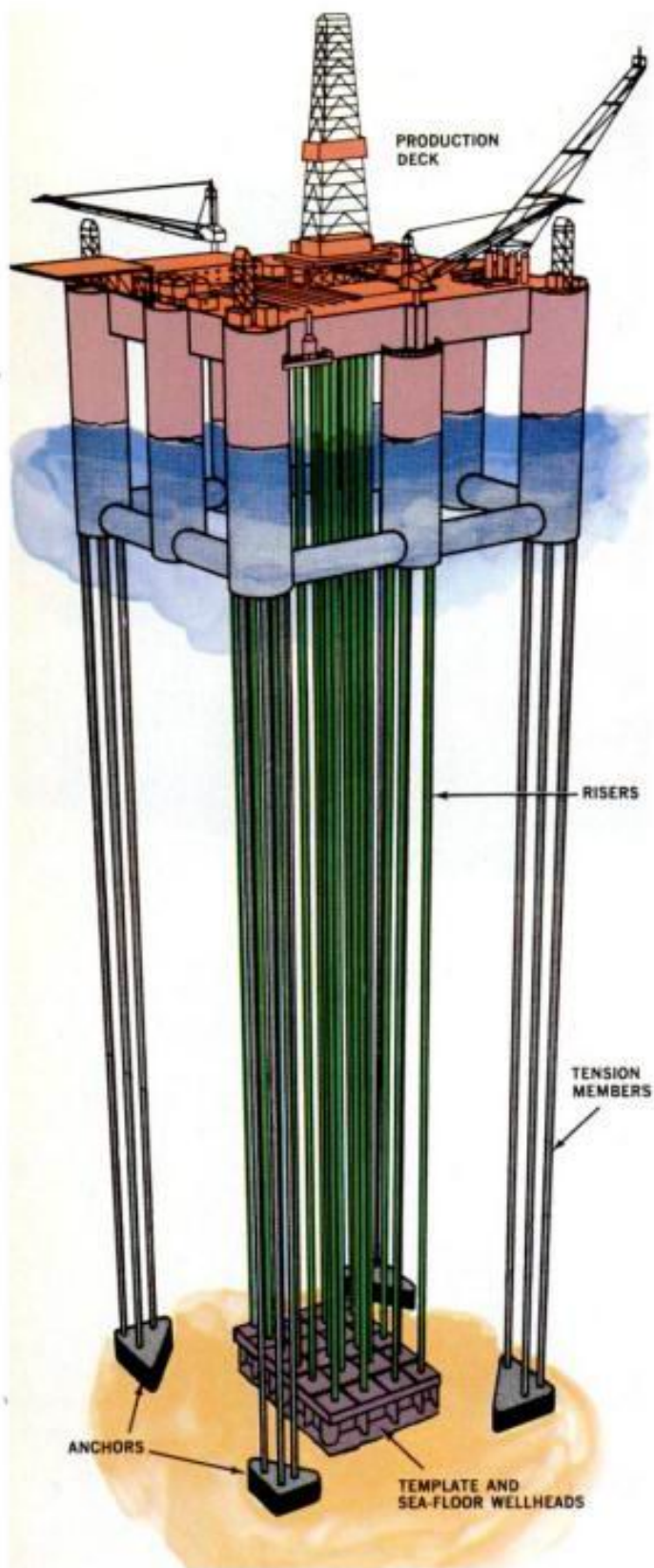
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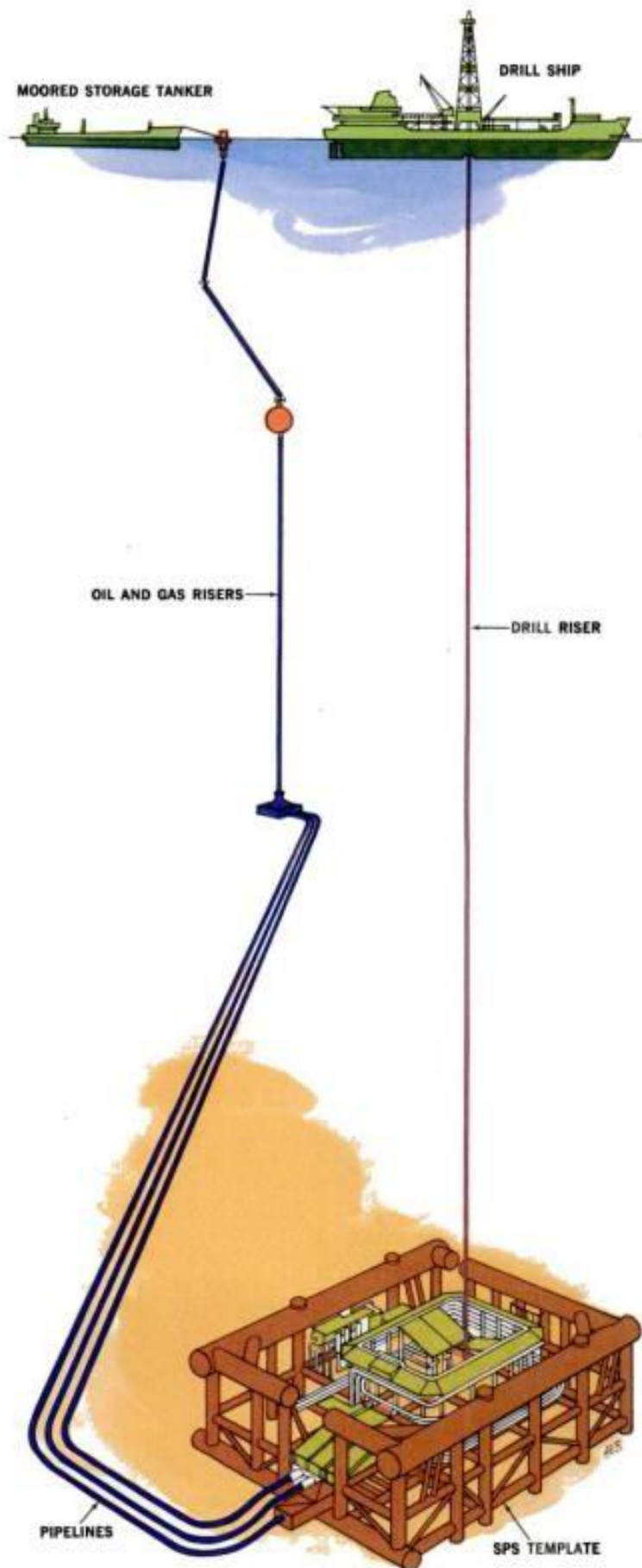
Barry Ross

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TENSION-LEG PLATFORM

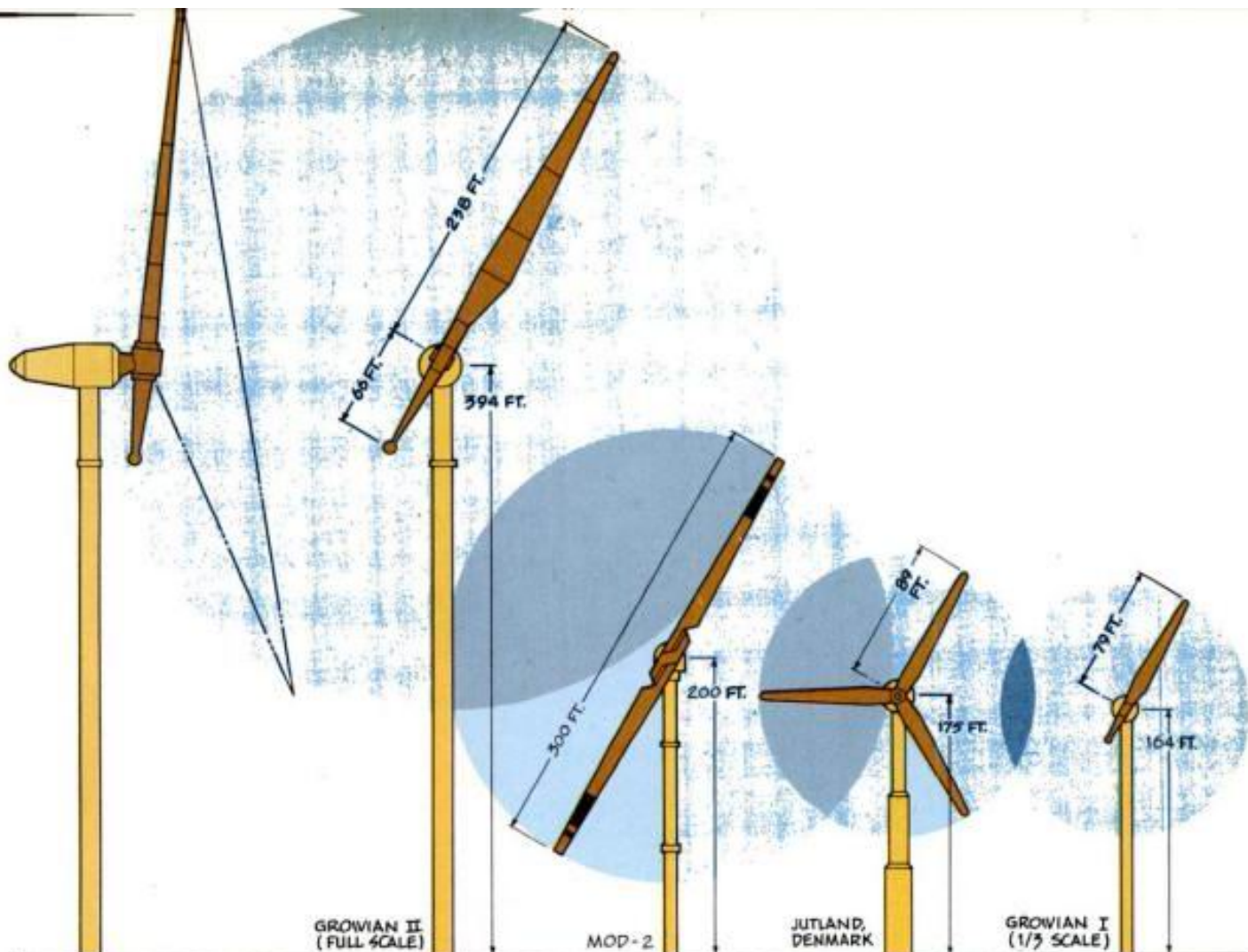


SUBMERGED PRODUCTION SYSTEM

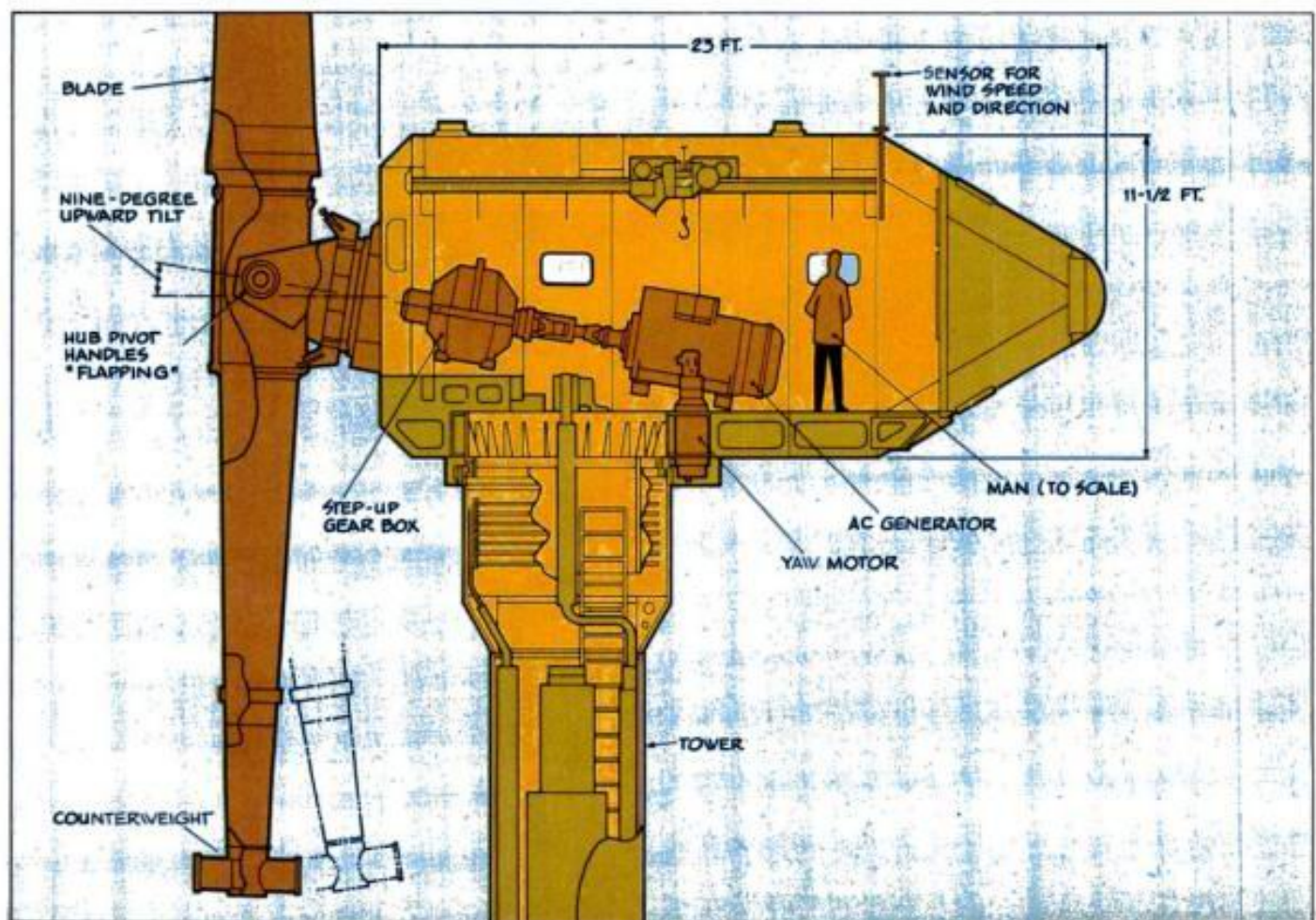


DRAWING BY ADOLPH BROTMAN

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Single-blade Growian II will be nearly twice the height of the two-blade Boeing/DOE Mod-2, currently the world's largest windmill. Even Growian I is nearly as big as the three-bladed windmill at Jutland, Denmark, the previous record holder.



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SATURN'S SECRETS

The week that stunned scientists

Tilt-engine V/STOL

speeds like a plane,
lands like a copter



Tilt-engine V/STOL

cruises at jet speeds,
hovers like a copter

Sophisticated new engines give this "Son of Nutcracker" amazing maneuverability

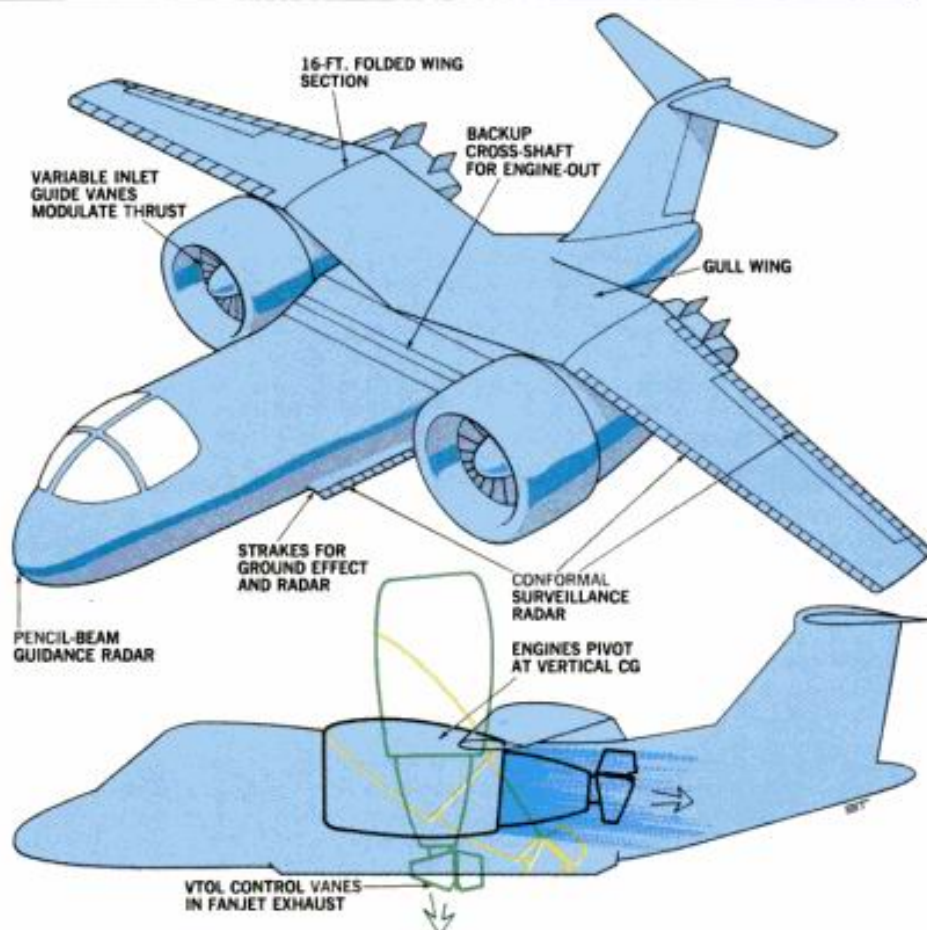
By BEN KOCIVAR

"This is the concept that could revolutionize our Navy." That's what experts are saying about Grumman's Design 698, the craft pictured on these pages and on the cover. To learn why, I visited Bob Kress, Grumman's director of advanced concepts.

At first glance, the shiny-white, seven-foot-long, radio-controlled model didn't look very different from a conventional Navy reconnaissance plane. True, the fanjet (also called turbopan) engines tucked under the gull wing did seem outlandishly large for the size of the plane. But what makes it revolutionary?

The answer, Kress told me, is that these engines can tilt from horizontal to vertical, for both fast forward flight and vertical takeoff and landing. Moreover, Design 698 tackles the problems that have plagued V/STOL planes of the past, including other tilt-engine designs. The result, according to Kress: It promises to combine capabilities that no other Navy or Air Force plane has. For example, it will be able to:

- Take off and land vertically from a heaving destroyer or cargo ship.
- Take off in less than 200 feet with overloads such as critical cargo and long-range missiles.
- Fly more than 1,000 miles and reach altitudes of 50,000 feet.
- Take over the functions of a half-dozen other specialized planes, includ-



Control vanes mounted behind each nacelle react to high-pressure air flowing behind each fanjet engine and pivot with the engine for vertical or forward flight.

ing "over the horizon" surveillance with a novel airborne radar (called "conformal" because it conforms to the shape of the plane) and other sensors that track enemy planes, missiles, ships, submarines, and even moving ground targets.

The history of past efforts in V/STOL aircraft, and an account of

Vanes provide yaw and pitch control. Roll control comes from varying angle of inlet guide vanes ahead of fan blades, controlling thrust differential for each engine.

how engineers are attempting to overcome their handicaps in Design 698, is typical of the trial-and-error evolution of modern aviation.

All the V/STOL planes until now suffered from problems of power, precise control in the hovering engine, and/or high fuel consumption. For

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Solar collector/converter

moves heat in chemical form

"Orchards" spread over the desert Southwest may reap the sun's energy

By RICHARD STEPLER

WASHINGTON, D.C.

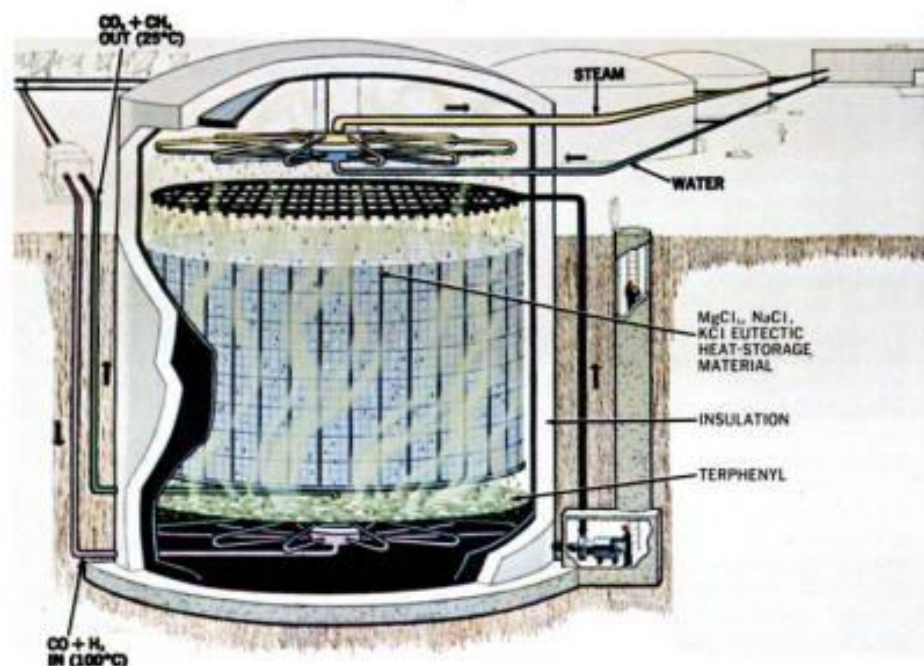
I stood at a large window overlooking the Potomac River, holding a curious object: a curved length of spiraled ceramic tubing, about 18 inches long. It was a segment of a prototype for a thermochemical solar receiver such as the one pictured on this month's cover. This receiver/converter is a crucial element in a sophisticated system that promises to deliver high-temperature solar energy for large-scale power production.

I was at the Naval Research Laboratory in the office of physicist Talbot

Chubb, who, along with project associates Del Simmons and Joe Nemecek, was explaining Solchem, a novel thermochemical solar-energy transport and storage system.

In Solchem, a gaseous working fluid changes its chemical form in order to absorb, transport, and liberate solar energy in an endless, closed-loop system. According to Chubb and his associates, thousands of individual solar concentrators and receiver converters produce an energy-rich gas. Then low-temperature, low-pressure pipes carry the gas, which contains solar heat in chemical form, over intermediate distances—say, one tenth of a mile to 10 miles. (One gas being considered could even use plastic pipe!)

The sun's energy is gathered at a central power generating facility where energy-storage boiler tanks en-



sure that solar power is available whenever needed. The stored heat is used to produce steam to drive conventional turbines to generate electricity.

I'd been following Solchem's progress for several years. Two recent key developments indicated that it was time to report on the concept:

- At the White Sands, N.M., solar furnace, for the first time ever, a thermochemical receiver converted solar heat into chemical energy. ("It performed better than we predicted," Talbot Chubb told me with a grin.)

In Solchem storage tank, working gas recombines in piping at bottom of tank, releasing heat. Heat-pipe fluid terphenyl boils, condensing on cans filled with eutectic salt, which store heat. At night terphenyl is sprayed over cans to maintain high temperature and vapor pressure in tank. Energy is withdrawn in form of steam at top of tank.



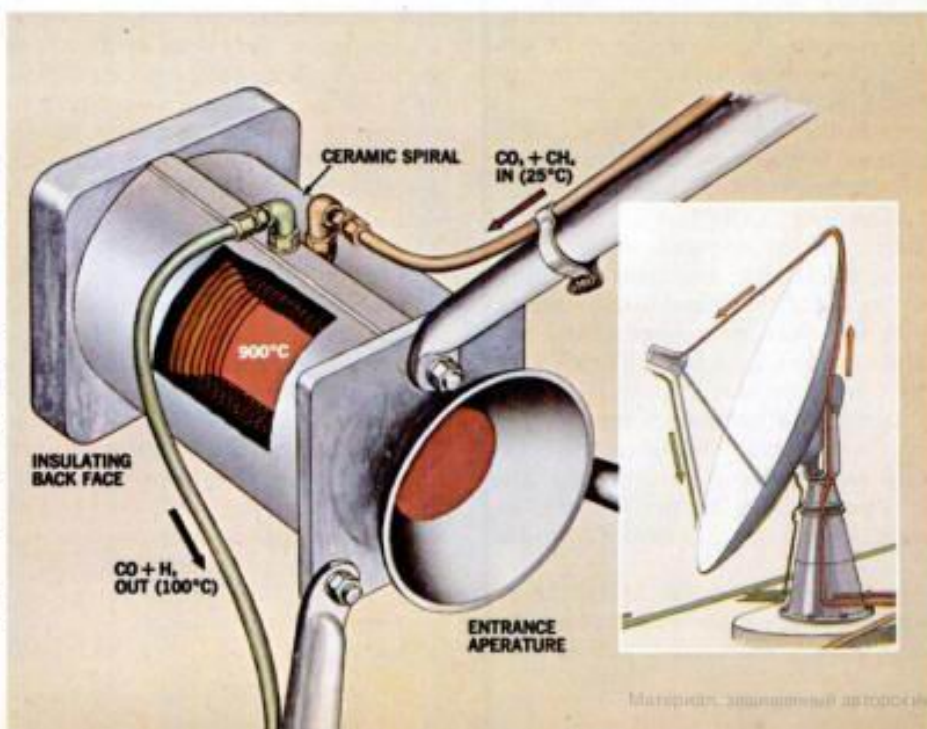
Solchem's solar-energy "orchard" would consist of thousands of paraboloidal concentrating collectors covering about 20 percent of orchard's land area.

Seven-meter-dia. (23 feet) paraboloidal collector concentrates sunlight onto thermochemical receiver/converter, which heats working gas to about 900 degrees C. Gas then passes over a catalyst and dissociates, absorbing heat.

- On the banks of the Potomac River in Washington, work on a two-MWh energy-storage boiler tank, containing 30 tons of eutectic salt, was nearing completion, with testing scheduled to be under way about the time you read this. (A smaller, laboratory tank has already been successfully demonstrated at NRL.)

Since I had just undergone NRL's mandatory security-clearance check, I

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The challenge of
ocean treasure,

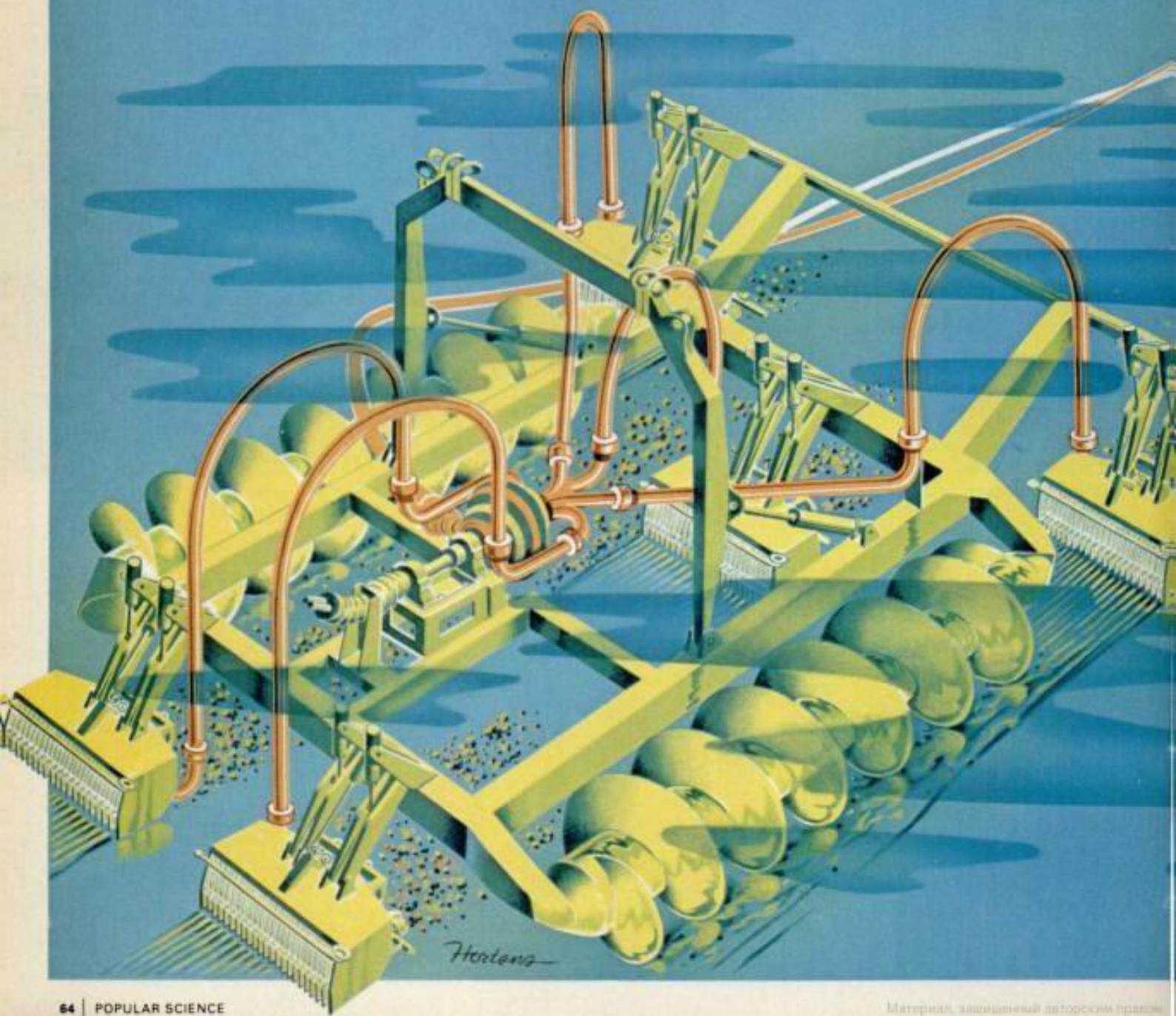
Deep- sea mining

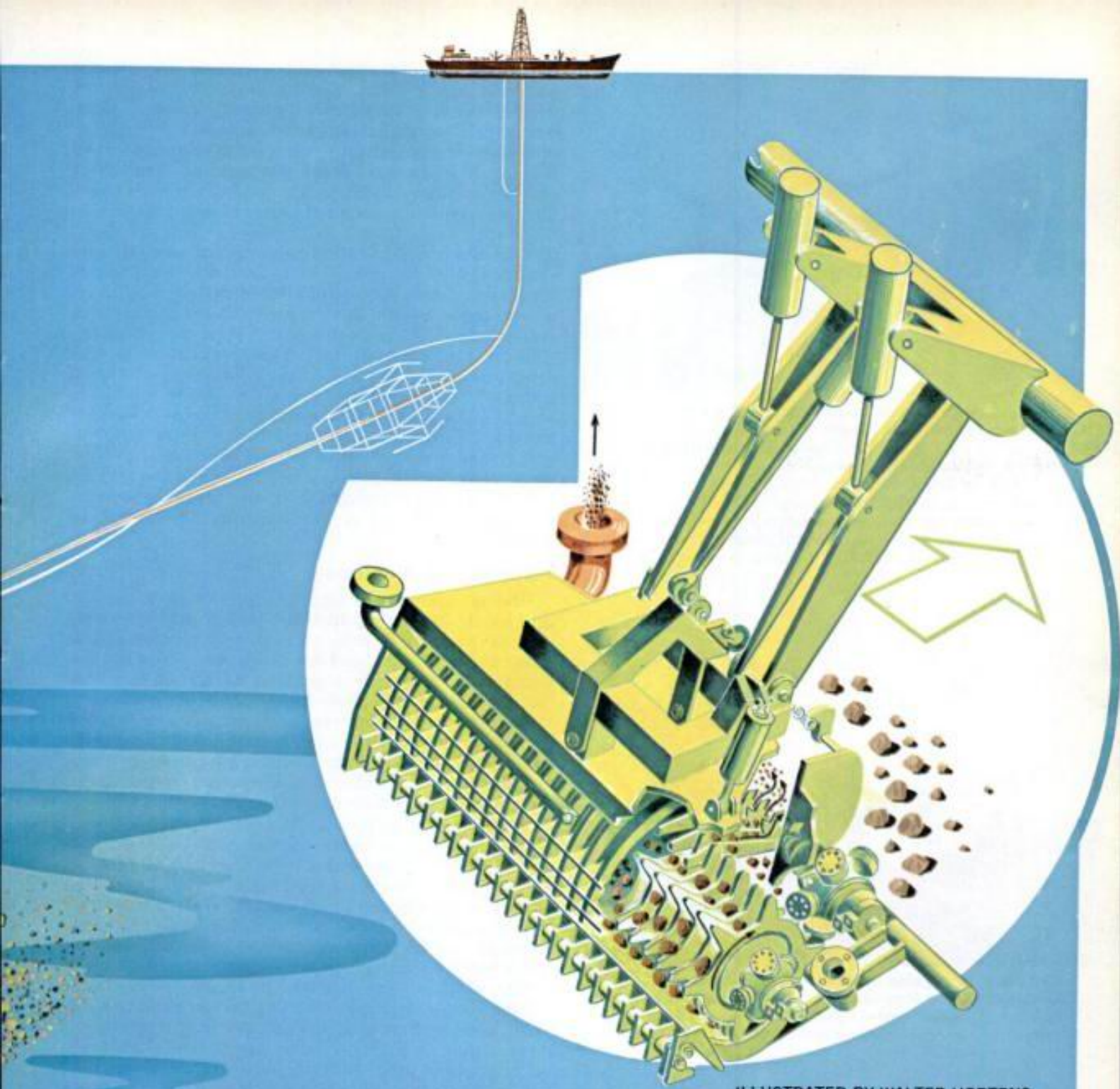
Mineral-rich manganese nodules are the prize. The technology to exploit them is untried; the politics unsettled

By **PETER BRITTON**

The deep-sea-mining ship *Lomis*, a 200,000-ton vessel with the maneuvering precision of a helicopter, comes to a dead stop some 1,700 miles south of San Diego in an area called the Clipperton Fracture Zone. As her powerful thrusters hold steady against a persistent current, sliding doors beneath the ship slowly open, exposing a 150-foot-long dredge head to the three-mile-deep abyss. The 250-ton machine is gingerly lowered on steel cables to a depth of 160 feet. Divers swarm about, checking connections, umbilical cables, a huge flexible hose, television cameras, lights, and sonar systems. A flotation

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ILLUSTRATED BY WALTER HORTENS

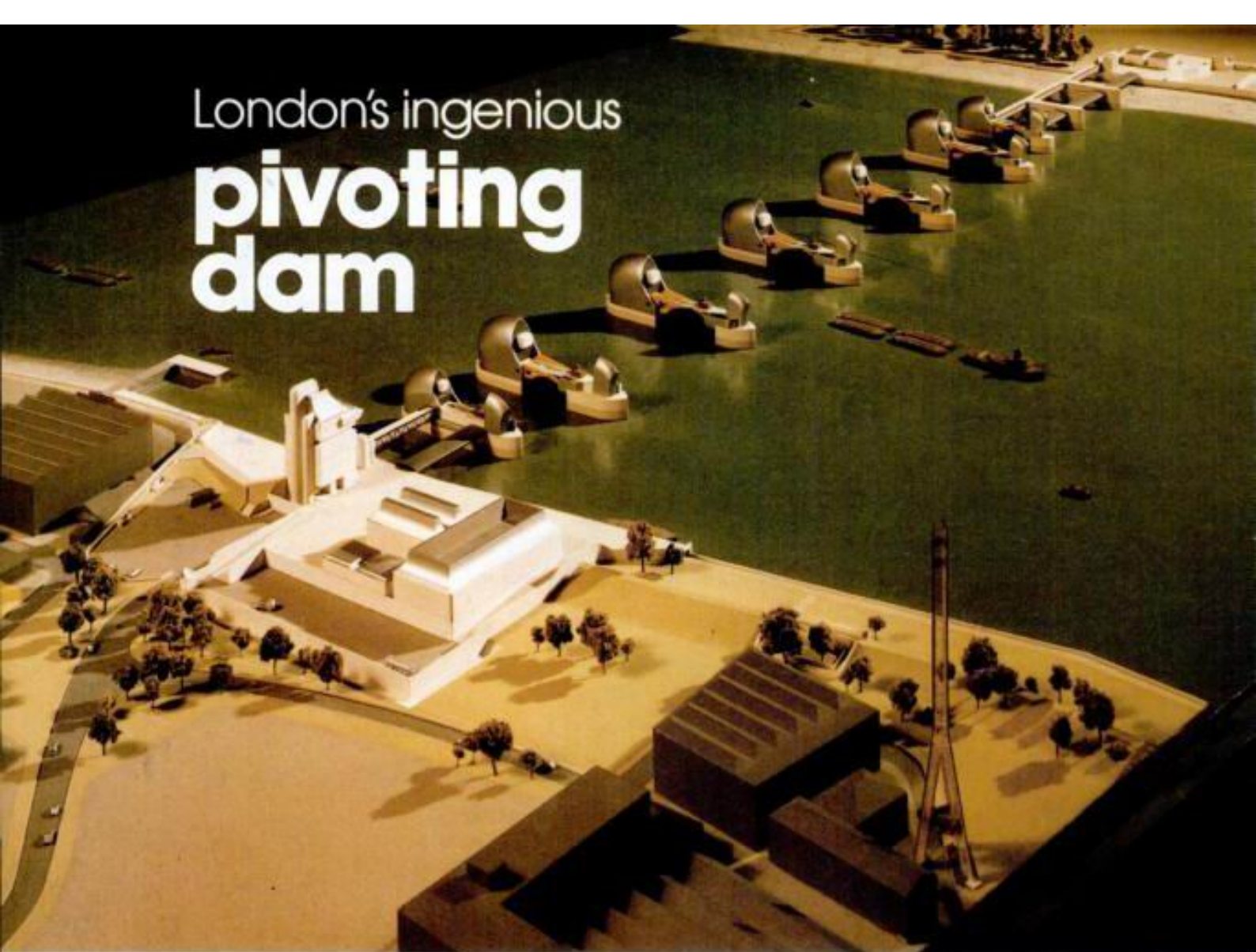
Deep-sea-mining system designed by Ocean Minerals Co. uses a bottom-crawling dredge head to pick up, wash, and crush manganese nodules and pump them to an intermediate rig called a buffer. A specially designed mother ship receives the slurry and provides the operational control and maintenance support for the underwater machinery. Here's how the system works: The dredge head, equipped with sonar, lights, and television cameras, and controlled remotely from the ship, crawls slowly along the ocean bottom propelled by the inward turning of its Archimedean screws. As it moves, its nodule-pickup heads (inset) rake nodules and mud from the ocean floor. As

the nodules rotate on the tines, water jets clean them of mud. They pass to the crusher where they are ground into small particles. These fall into an enclosure beneath the crusher and are pumped, in a slurry, to the conduits (shown in red) at the end of the pickup heads. One pump serves all conduits.

From the conduits, the slurry is pumped through a flexible hose to the buffer, which is generally located about 75 feet above the dredge head. The hose and connecting cables are held above the dredge head by a flotation block (not shown). The buffer holds the slurry temporarily; it also houses all the equipment not needed on the dredge head itself. The buffer is connected to

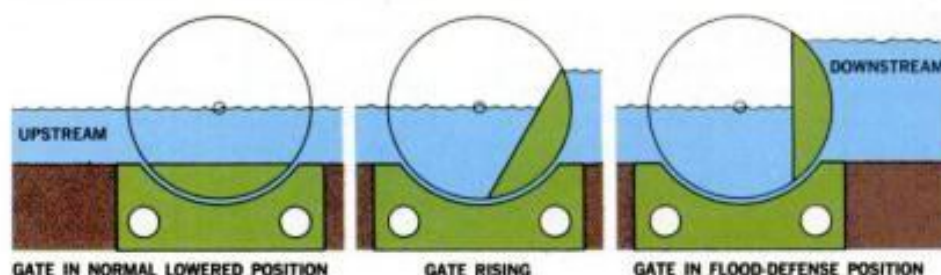
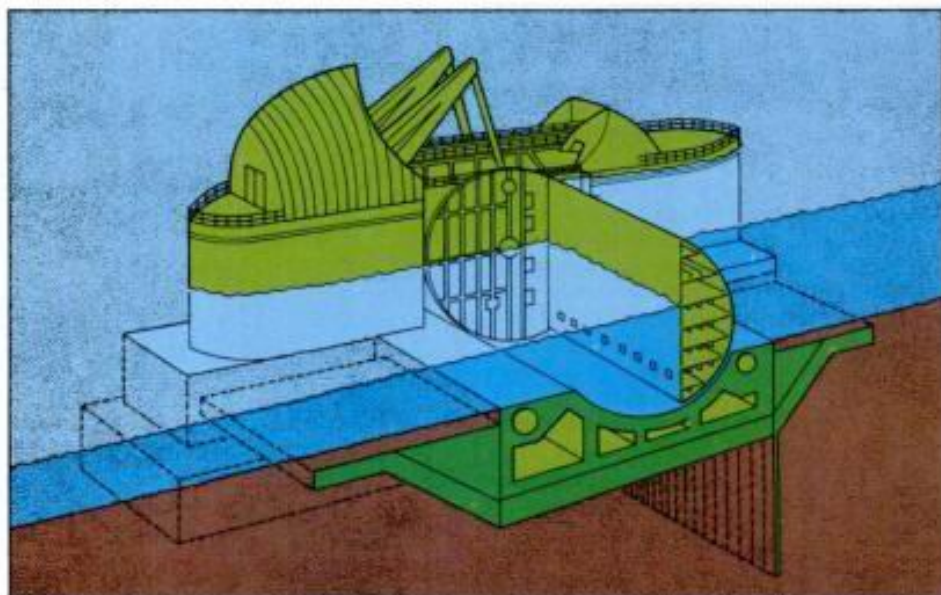
the ship by a rigid pipe. In the design illustrated, the slurry is raised to the ship through the connecting pipe by a system called an air lift: An air line from a compressor on the ship injects air into the pipe at a point about 5,000 feet below the surface. The air lowers the density of the fluid inside the pipe from the injection point to the surface. The total weight of the fluid inside the pipe, from top to bottom, is then less than the weight of the water outside. Thus, outside water pressure pushes everything in the pipe up to the surface. (Electric pumps or pressurized sea-water lifts could also be used to raise the slurry.) The nodules are transferred to large cargo vessels and hauled to shore.

London's ingenious pivoting dam



Model of the River Thames Barrier, as it will look in normal weather, is shown above. Between the concrete piers will be 10 steel gates that can be pivoted into defensive position when a flood tide threatens. The four main gates are in the middle of the river; these lie on the bottom in concrete sills and pivot up to form the dam (diagram, below right). Two similar but smaller gates flank them. Near the river banks are smaller gates (one on the left, three on the right), which will pivot downward.

When a flood tide is predicted, ships will be warned; then hydraulic equipment, housed in concrete piers (diagram, right), will begin to rotate the gates. Time to vertical position: about 30 minutes. When the surge recedes, gates will be returned to their sills and the river's outflow will resume. The Thames River Barrier project is sponsored by the Greater London Council, with grants from various government ministries. Consulting engineers Rendel, Palmer, and Tritton were appointed to design the barrier and supervise its construction. Main civil engineering contractor is the Anglo-Dutch consortium of Costain, Tarmac, Hollandsche Beton Maatschappij B.V.; Davy Cleveland Barrier Consortium is building the steel gates and operating machinery.

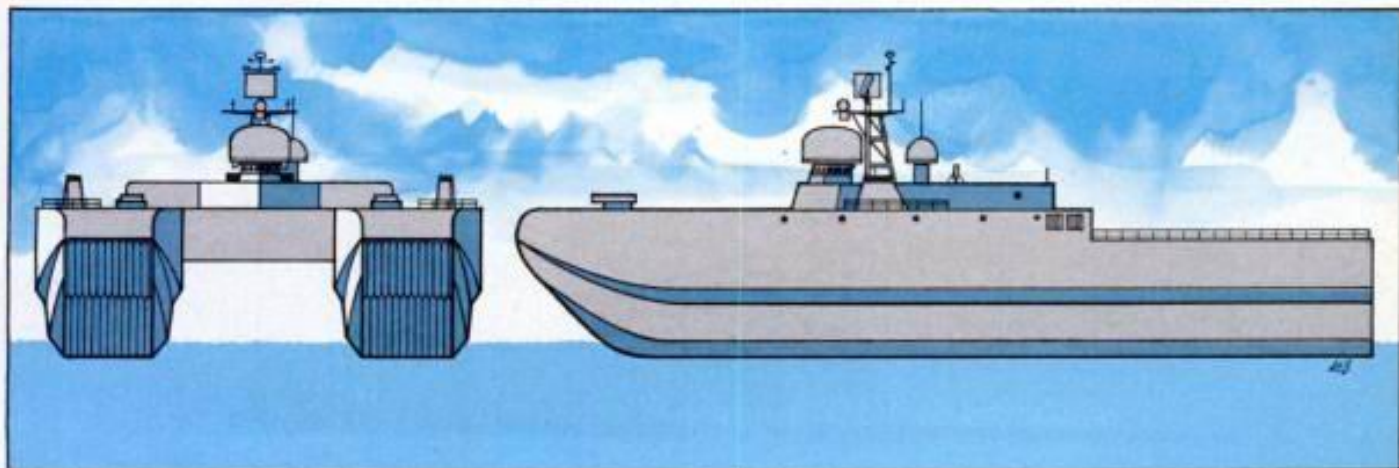




Hurting across heavy seas, the high-speed catamaran skims the surface, unlike the wave-battered conventional ship to starboard. Gas-turbine engines propel the cat, while twin bubbles of air under the curved catamaran hulls buoy the ship

above the seas. The only parts of the ship in the water (besides rudders and props) are thin, rigid, black sidewalls and flexible fore-and-aft seals extending down from each pontoon hull to enclose the air cushion. This surface-effect ship draws much

less water than conventional deep-draft ocean ships, so it needs neither channels nor deep docking. And the twin hulls make the ship faster, more stable, and proportionally lighter than surface-effect ships with only one hull.



Flexible seals at front (above, left) and rigid sidewalls (right) on each side of the pontoon hulls enclose the surface-effect catamaran's twin air bubbles. The sidewalls minimize air leaks, greatly reducing

the amount of power needed to pressurize the cushion. Small skags on the bottom of each sidewall are always underwater and keep the ship from sliding sideways. Because of the sidewalls, a surface-effect

ship can't travel over land as amphibious hovercraft do. But this surface-effect ship is less bothered by crosswinds, and can travel farther and faster on less fuel than conventional, soft-sided hovercraft.



Seaweed power

— renewable energy
from offshore
kelp farms

Giant kelp, grown on man-made arrays, could produce enough methane to fill our need for natural gas

By **CHRISTOPHER SWANN**

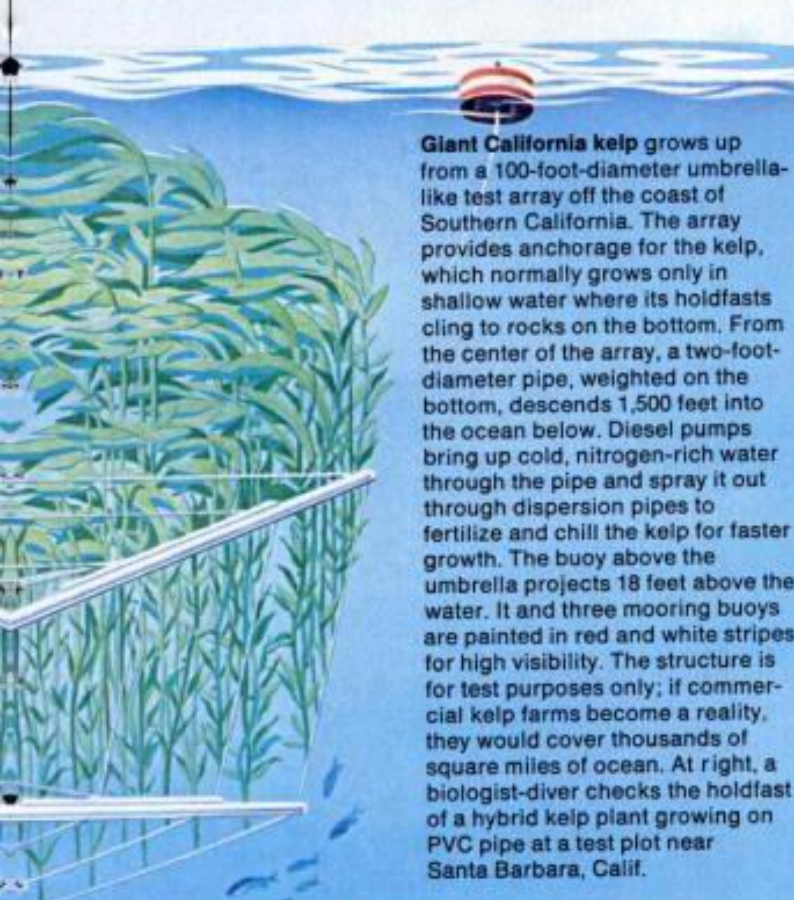
ILLUSTRATION BY WALTER HORTENS

Just off the Ellwood pier, about 12 miles west of Santa Barbara, Calif., is a most unusual farm. To inspect the crop, I have donned scuba gear and wet suit and descended 35 feet into the chilly green brine. Several acres of giant brown seaweed cling to a network of white PVC pipes. Their fronds rise toward the surface, creating a forest-like effect. Now and again, my biologist guide pauses on our tour to point out a plant. Some are only a few feet long; others reach to the surface. All are kelp hybrids, produced in the laboratory of Neushul Mariculture, Inc. The farm is the test plot for the newly hybridized plants.

About five miles off the coast of Laguna Beach, Calif., a strange umbrella-like array is anchored to the bottom nearly 2,000 feet below. Its spokes and connecting ropes,

buoyed above the abyss, were, until recently, also covered with kelp. Built and put in place by Global Marine Development, Inc., this Open Ocean Biological Test Farm, like the Neushul Mariculture plot, is part of an imaginative research effort known as the Marine Biomass Program. Its goal: a renewable and economical source of organic matter from which to make methane—the prime constituent of natural gas [PS, Dec. '74]. If the program is successful, giant open-ocean kelp farms covering thousands of square miles could one day produce enough methane to fill the natural-gas needs of the entire country. The program is sponsored by the Gas Research Institute and the Department of Energy, and is managed by General Electric.

Why produce biomass at sea when you can grow it on



Giant California kelp grows up from a 100-foot-diameter umbrella-like test array off the coast of Southern California. The array provides anchorage for the kelp, which normally grows only in shallow water where its holdfasts cling to rocks on the bottom. From the center of the array, a two-foot-diameter pipe, weighted on the bottom, descends 1,500 feet into the ocean below. Diesel pumps bring up cold, nitrogen-rich water through the pipe and spray it out through dispersion pipes to fertilize and chill the kelp for faster growth. The buoy above the umbrella projects 18 feet above the water. It and three mooring buoys are painted in red and white stripes for high visibility. The structure is for test purposes only; if commercial kelp farms become a reality, they would cover thousands of square miles of ocean. At right, a biologist-diver checks the holdfast of a hybrid kelp plant growing on PVC pipe at a test plot near Santa Barbara, Calif.



land? The principal reason is space: Cultivation on the necessary scale would take up land needed for food crops and other uses. Seaweeds of some varieties are also among the fastest-growing plants known to man and promise a high energy yield [PS, July '75]. Furthermore, seaweeds are superior to land plants for conversion to methane due to their high water content and lack of lignin, a woody supportive tissue. And they do not require irrigation or petroleum-derived fertilizers.

Even though growing biomass at sea solves some problems, it poses others. The main one: Natural beds of suitable seaweed are just not large enough to yield even a fraction of the 20 trillion cubic feet of natural gas the U.S. consumes each year. Establishing new beds presents another problem: The seaweed grows only in relatively shallow water—at a maximum depth of 100 feet—and there is simply not enough usable coastline at that depth for volume production. The solution: Move to the open ocean and grow the seaweed on vast tethered substrates. The umbrella-shaped Open Ocean Biological Test Farm was designed to test the feasibility of such arrays.

Harvesting the sea

Man has been using seaweed for a long time. The Japanese have collected it for food for at least 300 years. The kelp beds off California have been harvested since World War I—initially for potash and acetone, then as a source of algin for food additives and animal-feed supplements. Collecting ships clip the top few feet of the kelp fronds, as conveyors pull the harvest aboard.

In the late 1960's Dr. Howard Wilcox, an engineering physicist who had worked on the atom bomb at Los

Alamos, proposed using marine plants as a source of methane gas. His idea led eventually to the Marine Biomass Program.

To produce the maximum amount of gas at the lowest possible cost, project biologists chose a seaweed that is both very large and very fast growing: the giant California kelp, *Macrocystis pyrifera*. The largest of the marine algae, it grows in extensive beds from Alaska to Mexico at the prodigious rate of up to two feet a day, and reaches lengths of 200 feet in adulthood.

Fronds of the *macrocystis* extend from a rootlike holdfast. The holdfast serves only as an anchor, its tendrils grasping rocks or other solid objects on the bottom. It does not double as a nutrient-gathering system. The blades of the fronds bear gas-filled floats that raise the fronds so that they form a floating canopy near the water's surface. New fronds are continuously generated near the base as old ones die. Reproduction is prolific.

In its natural state, the California kelp is continuously fertilized only two or three months each spring when deep water rich in nitrogen wells up from the depths. For the rest of the year, the kelp beds must rely on stored reserves and sporadic upwelling. If the kelp-farm concept is to be economically viable, the yields typical of natural beds must be greatly improved. By how much? "As an educated guess, I would say a kelp farm might have to produce from four to 20 times as much as wild beds to be profitable in today's energy market," said Dr. Wheeler J. North of Caltech, who, together with Dr. Michael Neushul, director of Neushul Mariculture, is responsible for the biological aspects of the program. Dr. North and his colleagues think that one way to boost growth rates

Continued

8,000-foot wind-power tower

Solar energy would create a 150-mph wind in this gigantic chimney

By ERNEST F. BLASE
and JEROLD H. KLAIMON
ILLUSTRATION BY DEAN ELLIS

You've been aware for miles of a gray tower looming on the desert horizon. The closer you get, the more awesome it is, dwarfing any structure you've seen or imagined.

Soon another mystery: The arid land has given way to rows of robust crops. Here's a gentle, cool breeze.

Suddenly the fields end, replaced by damp black asphalt. A brisk wind and a loud "whoosh, whoosh" suggest what this gargantuan structure is.

The tower is a windmill of sorts—an aeroelectric plant. It's a simple concept, despite the tower's great size. Water, piped from the sea, is pumped to the top of the 1½-mile-high, 900-foot-diameter tower and sprayed through atomizers. It evaporates, cooling the hot, dry air. This cooled, dense air falls down the chimney and drives 10 wind turbines, which generate electricity—2,500 megawatts at peak; about 1,000 MW average.

Such a mammoth windmill doesn't yet exist, but an El Segundo, Calif., engineering firm, Agbabian Associates, has been studying the concept since 1978. The idea actually dates to 1965, when Dr. Phillip Carlson was working on a desalination project at Lockheed. "It involved condensing water inside a chimney," he recalls. "We ran some calculations and found that, theoretically, we'd get out eight times the energy we put in to pump the water to the top of the chimney.

But, in 1965, there didn't seem to be any need for new energy sources."

By 1974 the need was apparent, so Carlson resurrected the concept. In 1978 he joined Agbabian Assoc.

Power in volume

A comparison with a hydroelectric power plant illustrates why an aeroelectric plant must be so large. The quantity of power produced by both systems depends on the volume, density, and velocity of the working fluid: water in the hydroelectric system, air in the aeroelectric. Since air is much less dense than water, an aeroelectric system requires about 1,500 times more air than a comparable hydroelectric plant uses water.

Some of the power produced would operate ancillary equipment, and there would be power and friction losses. These amount to proportionally less in larger systems—another reason to build them big.

The proposed 2,500-MW aeroelectric plant would use 140 million cubic feet of air per second, which would require 1,000 cubic feet of water per second. Only the ocean would serve.

The velocity of the air coming down the chimney depends on the temperature difference between the air on the inside and that on the outside. The hotter and drier the ambient air, the more it could be cooled by evaporation. Thus the greater the temperature difference, the greater the power output. Consequently, aeroelectric towers are proposed only for desert areas.

Because hotter, drier air results in greater power production, an aeroelectric plant would produce maximum power on summer days and the minimum on winter nights. That, coincidentally, matches the demand curve of most electric utilities.

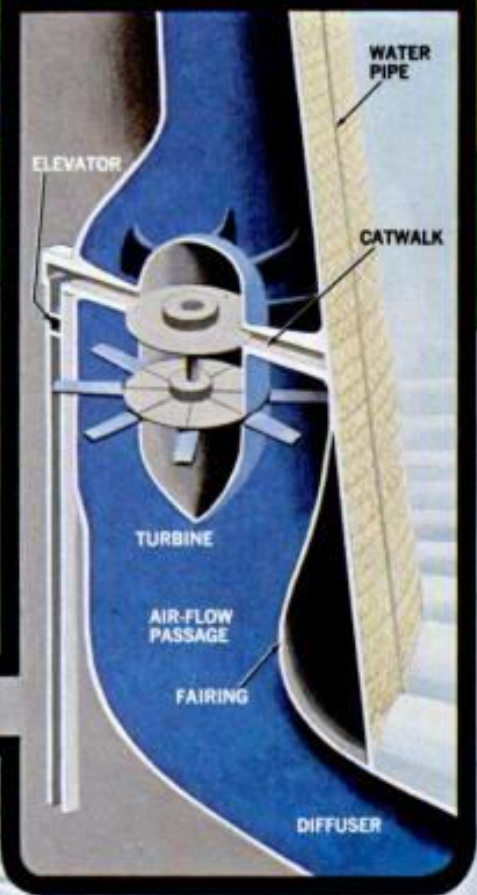
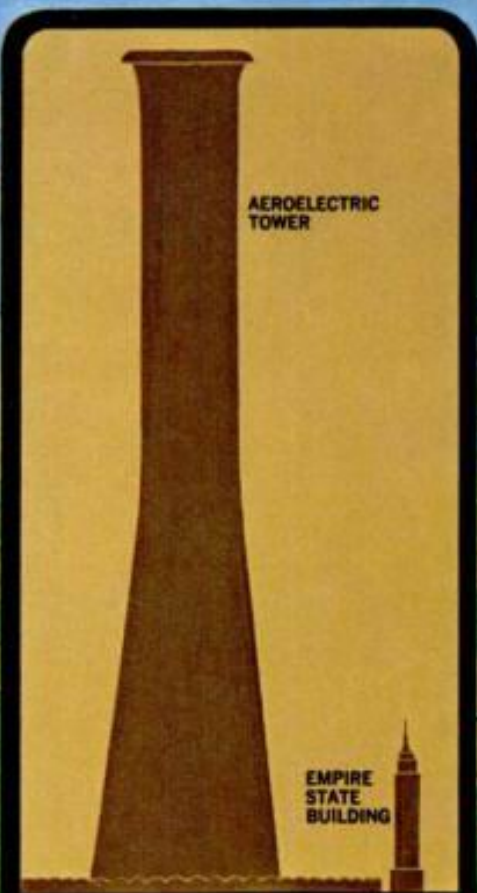
Agbabian admits that constructing an 8,000-foot tower presents a challenge. The current proposal calls for using prefabricated concrete modules with an inner wall only a foot thick strengthened by a lattice of concrete beams extending 30 feet out.

Just how much such a plant would cost is hard to say, but the company believes it would compare with other large power plants ("on the order of two billion dollars"). And it would be substantially less expensive to operate. The 2,500-MW tower would produce electricity at about one-third the cost of an oil-fired plant, Agbabian concludes, and significantly less than a coal or nuclear plant.

While an aeroelectric plant poses no known environmental hazards, it would certainly modify the microclimate. Air temperatures at the base of the tower would average about 30 degrees below ambient, and a 25-mph wind would blow out of the diffusers (the arched openings at the base of the tower). A salt-removal system is designed to take 99.9 percent of the salt from the sea water. The brine would collect in the diffusers and on the asphalt and be piped back to the sea.

The remaining moisture in the air would condense out at night as a very heavy dew, "... equal to 40 inches of rain per year near the chimney," says Carlson, "tapering to 20 inches three miles away."

Agbabian now has a \$5 million grant request ready for DOE. The funds would go for more studies and for a demonstration project that would use the Hoover Dam spillway as a simulated chimney. The next step would be a commercial plant: a 4,000-foot tower, 800 feet in diameter, producing 500 MW at peak power. [3]



Idany Ellis



Monster piers

for world's biggest flood-control project

Strange and ingenious new machines help complete a sea barrier

By DAVID SCOTT
ILLUSTRATIONS BY BARRY ROSS

ZIERIKZEE, NETHERLANDS

"It's like a cathedral!" I said to Gerard Baijens, my Dutch guide. My voice echoed back in the immense chamber we'd just entered—the hollow base of a 131-foot-high concrete pier. This cavernous boom-box would eventually be part of a 5.5-mile-long flood-control barrier to protect a corner of Holland from the sea.

The giant structure—six interconnected chambers, each the size of a three-story house—was standing dozens of feet below sea level. But it was inside a dry 250-acre pit on a man-made island in a wide estuary facing the stormy North Sea. I was at the heart of the biggest hydraulic engineering project the world has ever seen.

Called the Delta Plan, it's a series of dams or barriers linking five large islands on the Dutch coast below Rotterdam. I was visiting the Eastern Scheldt barrier site, the final, most exciting, and most difficult stage of the Delta Plan. The \$2 billion section is targeted for completion in 1986.

The barrier plan began in 1955, two years after violent storms burst dikes that protected land below sea level. Over 1,800 persons drowned. Livestock, farms, and homes were destroyed. To prevent it from happening again, the Netherlands government began a complex \$4 billion project that includes four long barriers at the seaward ends of the islands.

In addition, there are seven inland

shipping locks, sluice gates, and smaller dams for water management. Fresh river water replacing salt water because of the project makes some island farmland more arable. Roads topping the dams improve travel, so a vast industrial estate is planned. But the Eastern Scheldt posed special problems.

"The original scheme called for a simple dam like the others—pretty easy to build," Baijens told me. Environmentalists noted that sealing off natural tidal flow would destroy fishing and oyster beds, and upset the ecological balance for other marine life and birds.

So in 1976 the plan was changed from a dam to a storm-surge barrier. The new plan calls for 66 giant concrete piers across the estuary. Sliding steel gates between the piers will normally be open, avoiding disturbance of the environment.

Moon landing

"It's like the first landing on the moon," says hydraulics engineer Baijens. "Nothing like this has ever been attempted before." An artificial island started for the dam was enlarged for factories, harbors, a power station, and sunken construction docks to make gigantic piers.

Standing on an enclosing dike for one of these docks, I looked across at 19 of the towering monster piers. How could these incredible 18,000-ton piers be moved miles into place? "Early in 1982 we'll breach the outer dike," Baijens said, "and this first bay will be flooded to sea level at a water depth of 15 meters [49 feet]." He explained how an unusual 295-foot-long transport vessel will then maneuver into the flooded docks. Twin portal cranes (see illustration) will hoist each concrete

pier 36 feet off the bottom. In salt water, pier weight is halved by buoyancy to 9,000 tons.

Readying the sandy sea bottom for the giant piers involves some astonishing equipment, too. The sea bed is first compacted by a bargelike ship with four long vibrating "needles." Cylindrical finned heads on these shafts penetrate the porous sea bed to a depth of 50 feet. An axial vibration frequency of 25 Hz then begins as the compaction shafts are withdrawn in one-yard steps.

Giant mats

The next step covers the base areas for piers with huge mats to avoid sand erosion from tidal currents. These mats are 14 inches thick and have three separate layers of small stones on top, with gravel and then sand below. Plasticized fabric separates these graded layers, and long steel spikes stitched through the layers hold the porous mat together.

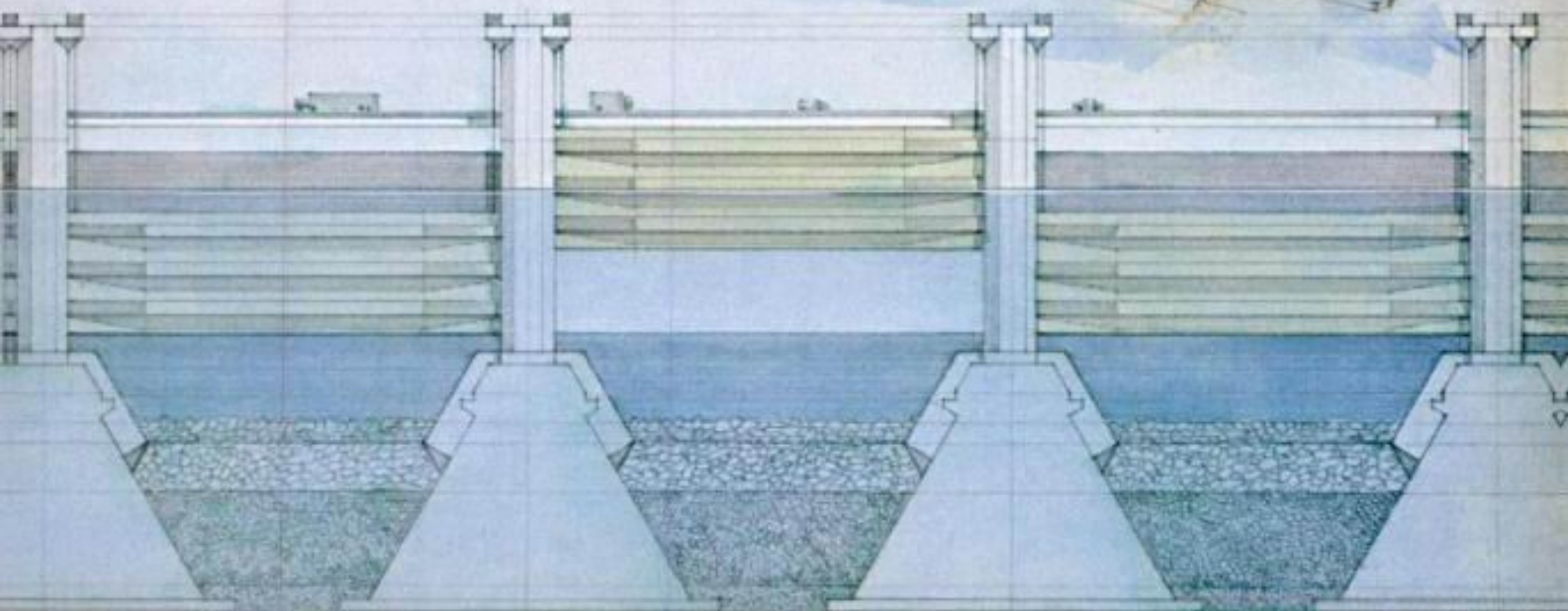
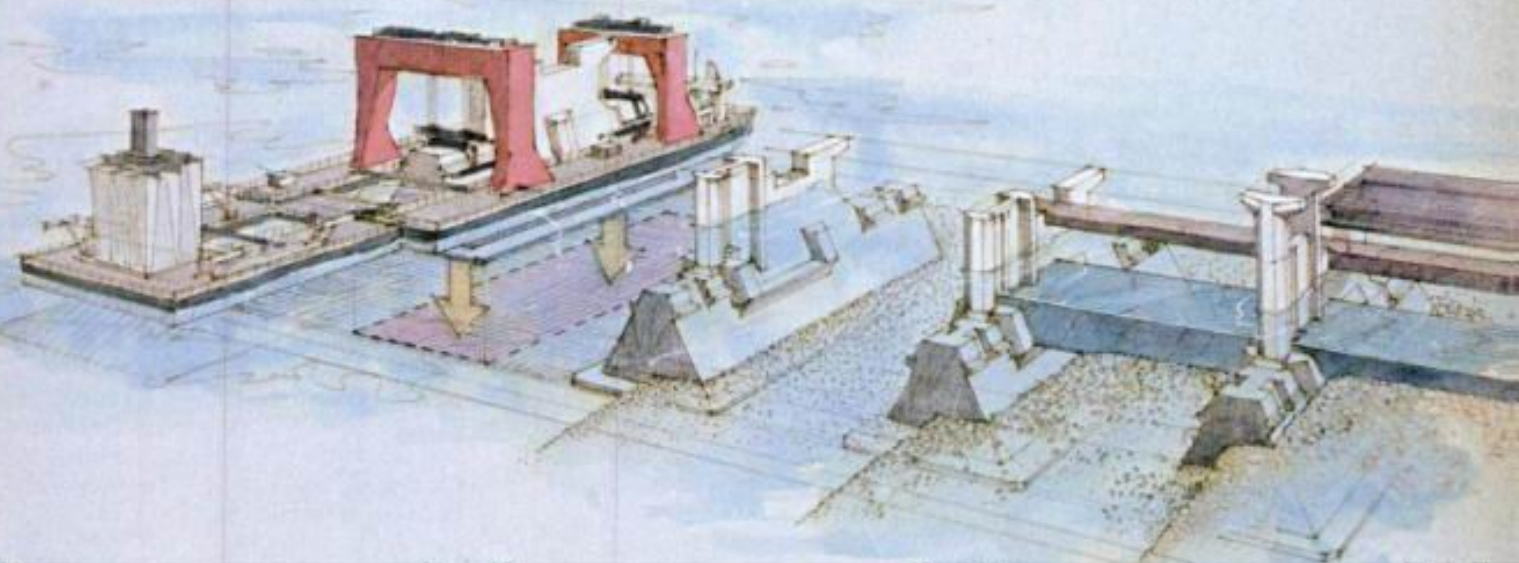
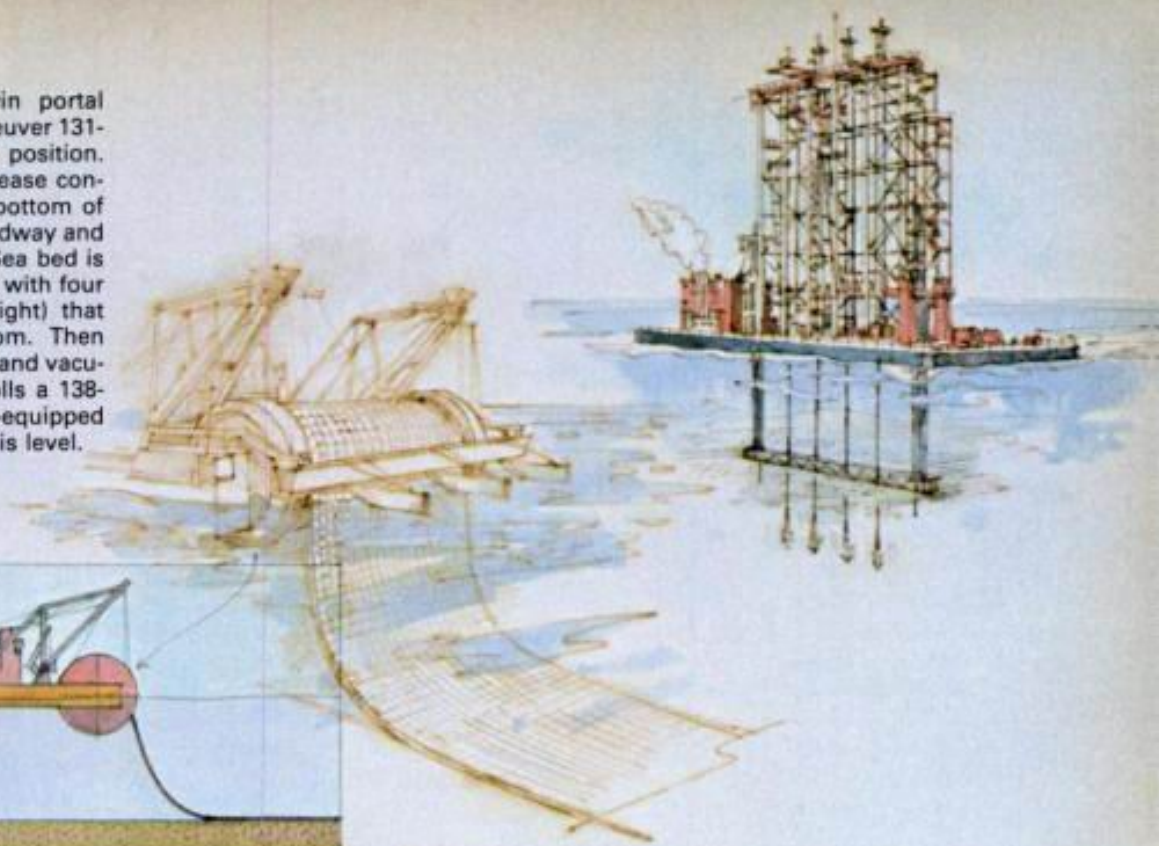
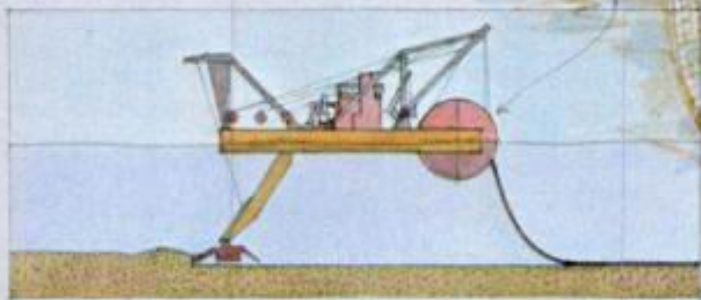
At one large low-level building on the island I watched in amazement as one of these massive 138-foot-wide layered mats oozed like ribbon toothpaste from one end of the building.

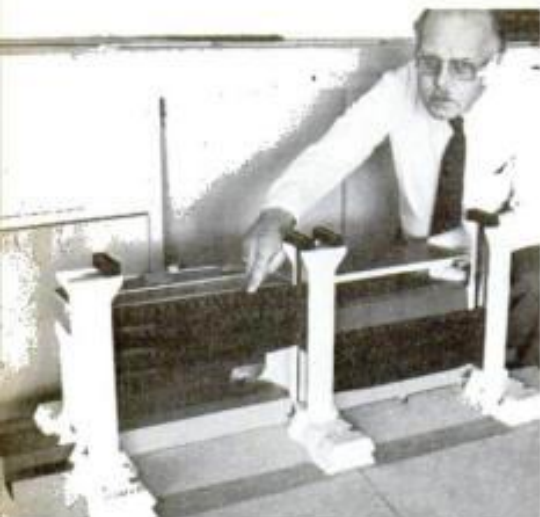
As the mat emerges from the plant it's wound in 219-yard-long rolls 53 feet in diameter. Despite its 5,500-ton weight, a mat drum floats. It is unwound along the prepared sand by a special pontoon ship. This weird craft performs other tasks, too. As the mat unwinds, a broad scraper blade beneath the vessel levels the sea bed. At the same time, an array of suction nozzles cleans the area just before the mat.

Then the ship makes a second pass to compact the mat with hammering feet that are lowered to the bottom on

Continued

Straddle-carrier ship with twin portal cranes (center, below) will maneuver 131-foot-high, 18,000-ton piers into position. Twin cranes on vessel then release concrete piers, dropping them to bottom of estuary. Piers will support a roadway and storm-surge barrier (bottom). Sea bed is first prepared by bargelike ship with four 141-foot-long "needles" (far right) that compact the sandy sea bottom. Then another vessel (below) scrapes and vacuums the sea bottom as it unrolls a 138-foot-wide foundation mat. A TV-equipped "bottom crawler" ensures mat is level.



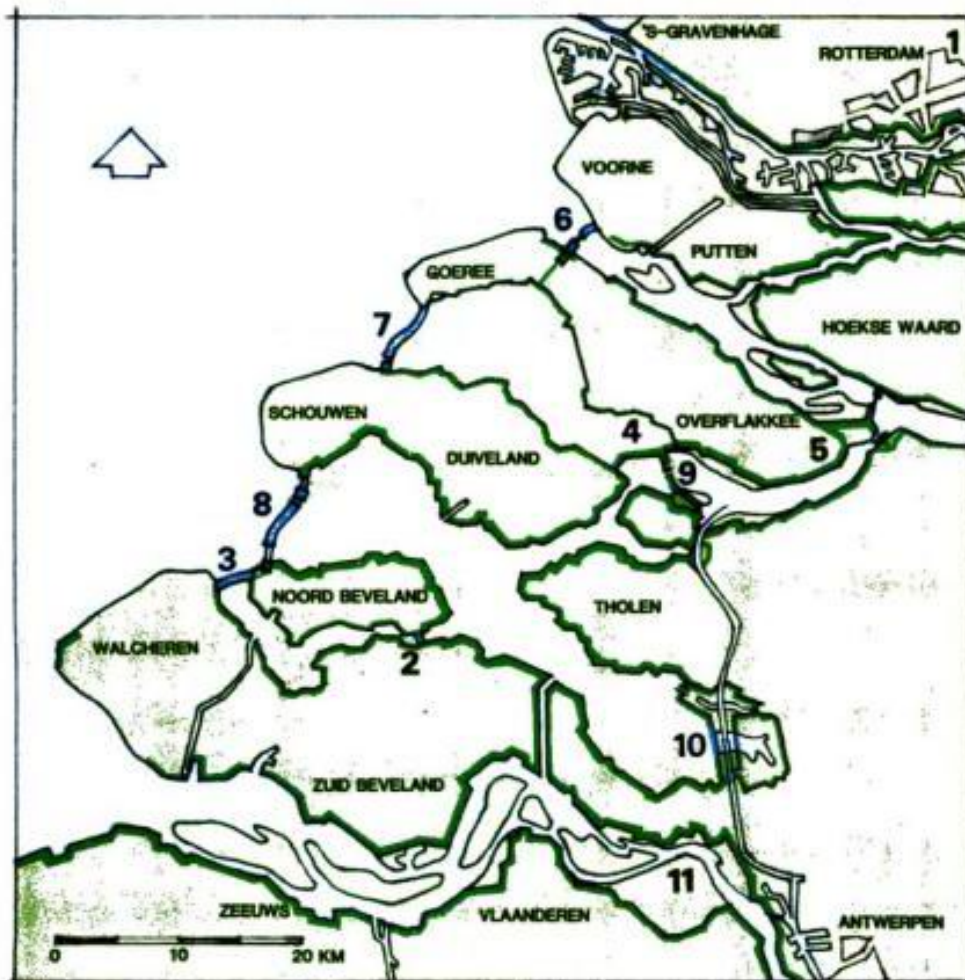


Storm-surge barrier will have sliding steel gates opened for normal tidal flow. Roadway will be 174 feet above bottom.



Dry construction dock built 49 feet below sea level has dike enclosing first batch of 19 piers. When dike is breached, sea water

will flood in to point where PS European Editor Scott stands. A ship will then float piers out, dropping them on special mats.



TIDAL, SALT

TIDELESS, FRESH

REDUCED TIDE, SALT

SEMI-STAGNANT, SALT

SEMI-STAGNANT, SALT OR FRESH

HEIGHTENING OF THE DIKES

Delta Plan projects, completion dates:

1. Storm-surge barrier Hollandse IJssel (1958). (Not shown.)
2. Sandkreek Dam with lock (1958).
3. Veerse Gat Dam (1961).
4. Grevelingen Dam with shipping lock (1965) and sluices (1985).
5. Volkerak Dam with shipping locks and inlet sluices (1970).

6. Haringvliet Dam with sluices (1971).
7. Brouwers Dam with sluice (1972).
8. Eastern Scheldt Dam with storm-surge barrier (1986).
9. Philips Dam with locks (1985).
10. Oysterdam with shipping lock (1985).
11. Sluice bordering lake (1985).

other arms. And finally, a tethered remote-control "crawler" equipped with a pivoted sensing beam and TV camera ensures that the mat surface is dead level. But even this isn't enough. A second, smaller mat resembling a cogged belt is laid over the first at each pier-base site. It compensates for any unevenness in the lower mat.

Piers will be sunk at low tide when there's no current flow. First, though, another vacuum-cleaner ship removes any drifted sand from the pier site. It's anchored nearby as a reference for the pier transporter. Speed and timing become essential. The water is still for only a few minutes.

With the pier in place, large rocks graded from 22 pounds to 10 tons are dropped around the tapered base. This weighs it down and protects the foundation from strong tidal currents. "These stones come from Germany and Finland," Baijens said, "since we have none in Holland." The stones are dumped from barges.

Baijens expects it will take 22 months to position 66 piers in three lines between the estuary banks and two artificial islands. Connecting beams, the sliding gates, and four-lane road sections will follow.

After this the piers are bonded to their support mats. Cement will be pumped through small mat holes into a shallow cavity beneath the pier base. Then the entire hollow base is filled with sand ballast brought to each pier by dump trucks.

Flood-control gates may be closed only once or twice a year during gale warnings. Little Holland, to guard its safety and environment, has achieved new heights in hydraulic engineering technology. The barrier is a monument to human values as well as to the technology.

Zwemmer said. "During wind calms, this head of water would be released to spin the turbines. With blade pitch reversed, the machines would run as generators, feeding electricity into the national grid."

The scheme has progressed beyond the stage of maps and drawings. The Netherlands government has given the go-ahead to a pilot scheme at Petten, north of Amsterdam.

Rising 72 feet above the sand dunes, the Petten windmill has an 82-

ft.-diameter downwind rotor. Precision controls provide near-constant rotational speed to the windmill's 300-kW generator, which provides power to the local AC grid.

Equipment at this research site checks aerodynamic behavior of the blades, monitors the forces bearing on the concrete mast and foundation, and records structural vibrations.

The lone windmill at Petten is the product of five years' research. Soon, 20 more like it will rise at a similar

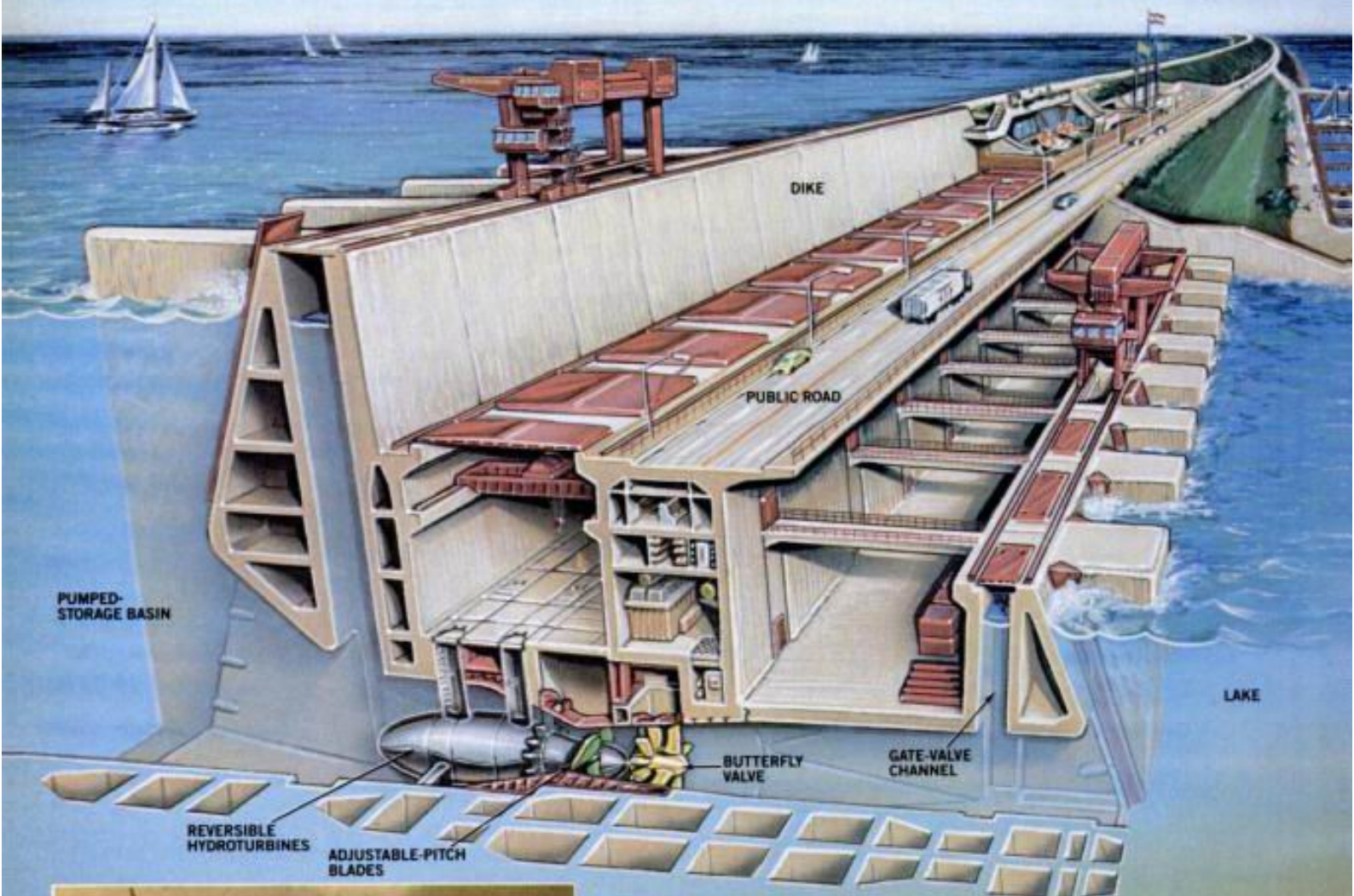
coastal site. This government-sponsored wind station is scheduled for construction early next year. Experience gained from the experiment will determine the next step.

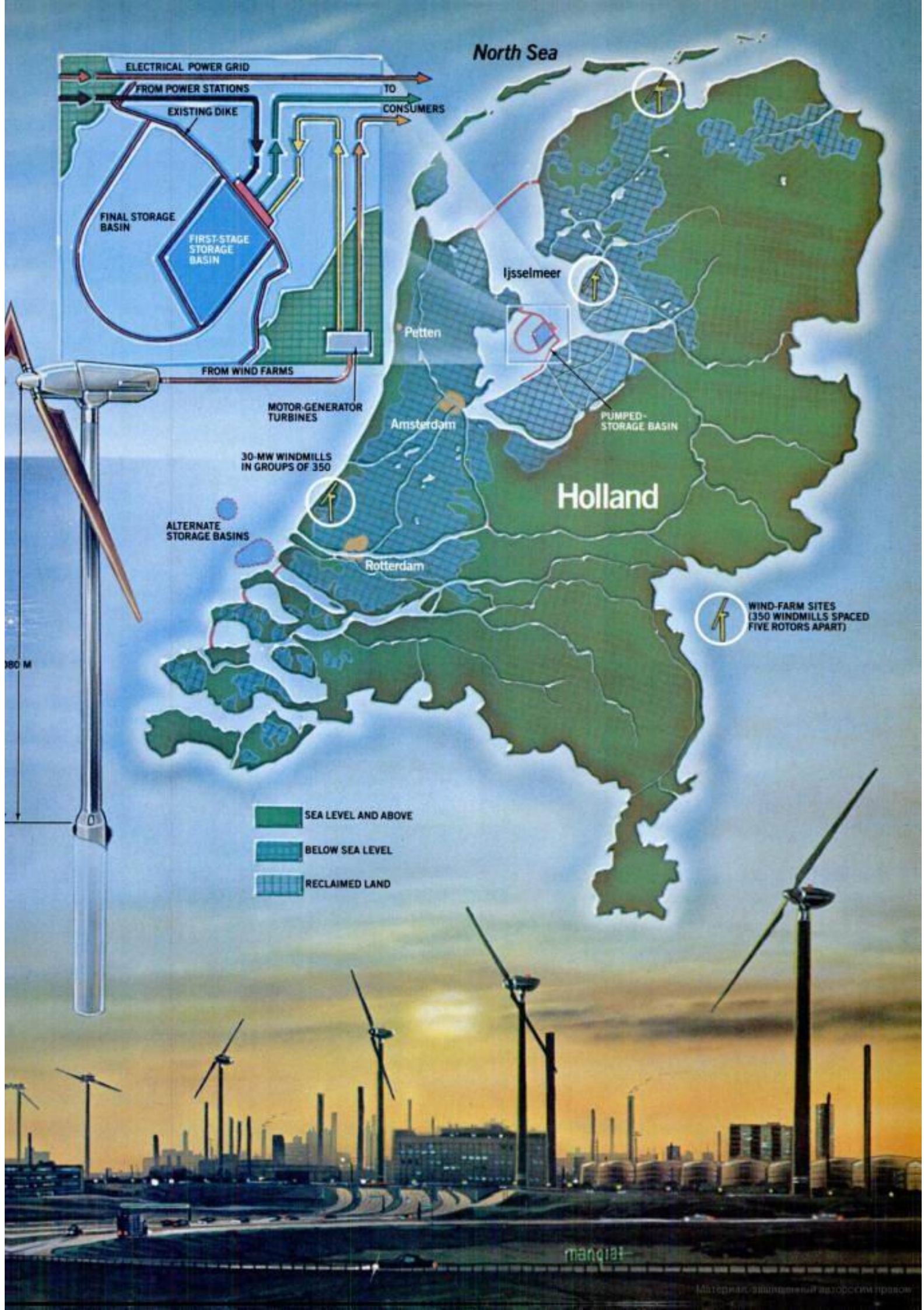
Though not all Dutch citizens share Lievens's grand vision, his giant-windmill scheme is likely to materialize in some form. The final decision will be made in 1985. Hydraulic energy storage could then be only a step or two ahead, for little Holland is a think-big nation. **ENR**

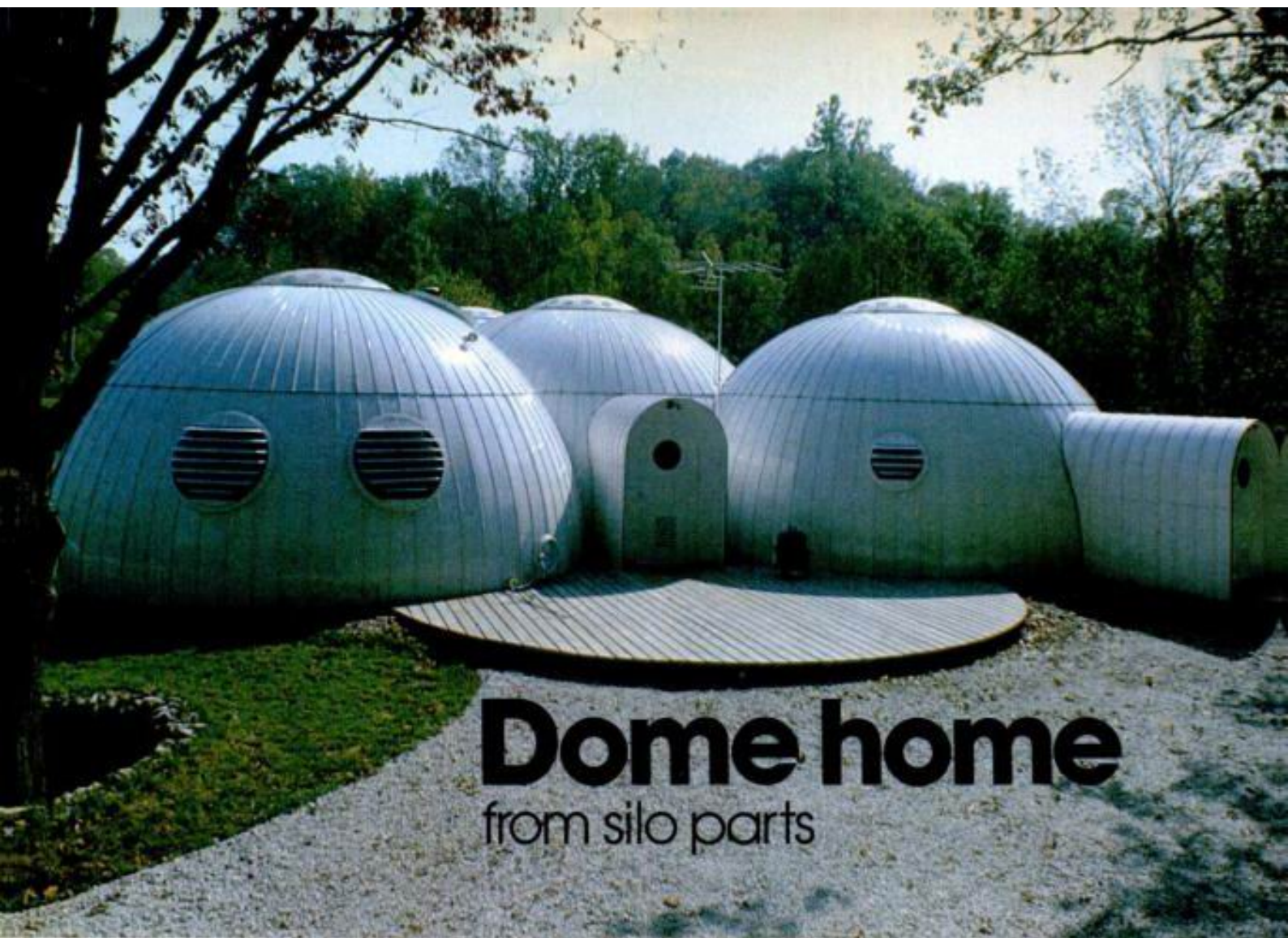
Giant windmills pierce Rotterdam's skyline (below, right). The array is one of three huge wind farms planned for Holland by the year 2000 (map). An experimental windmill now operating at Petten (inset) is one-tenth the size of the planned three-MW version below. Grouped on a common power line, the windmills feed

electricity directly into the national power grid (schematic, right). At off-peak times, wind-generated electricity flows to 48 turbines at the base of the IJsselmeer Dike (map). In its final form, the dike will enclose 64-sq.-mi. reservoir. The Kaplan turbines (illustration below) pump water into the reservoir until the wind fails. Then the

flow reverses and the turbines generate electricity, producing 50 MW each. When turbines aren't pumping, butterfly valves seal off input channels to maintain water level in the reservoir. Gate valves, raised and lowered by cranes, isolate the turbines for drydock servicing. System will produce 12 percent of Holland's power.







Dome home

from silo parts

Super-insulated twin-wall domes merge like soap bubbles to make a home

By **EVERETT H. ORTNER**
PHOTOS BY KRISTEN PETERSON

"Super-insulated dome clusters," their designer, Michael E. Jantzen, calls them. He makes them from the steel igloos that form the roofs of silos in farming country. Jantzen punches holes in them for doors and windows, stuffs them with insulation, and designs handsome furniture for them that suits their special conformation. He and his wife, Ellen, built their first house of silo components in 1974. Later, with Ted Bakewell, he built the Autonomous Dwelling featured in *POPULAR SCIENCE* [April '80]. Now he's done it again, with a new prototype dome-housing system.

His goal: to build a modular house that could respond perfectly to the needs of its owner—even grow and shrink in size. "You could start off cheaply, add space as your family grew, then shrink the house when the kids were gone—even give the kids a dome to grow their own house."

Jantzen has been working with the

[\[Continued on page 128\]](#)



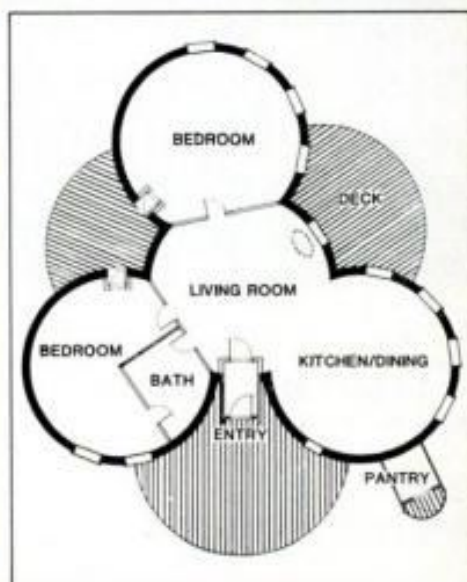
DOMES CLUSTER consists of four hemispheric silo-roof units made up of two-piece (upper and lower) galvanized-steel sheets, called sheets. These are two feet wide at bottom, and bolt together at bottom, center, and top. Domes come in different sizes, up to 32 ft. diameter; Jantzen used 26-footers for outer shells. He started with center dome (top photo, with entrance), assembling sheets clockwise. After making cutouts where the dome would join other domes, he started assembling others, making cutouts in those, too, as he came to matching points. Domes were then joined with an arch assembly designed by Jantzen. Inside the

26-ft. shells he now began to install 24-ft. inner domes. As sheets came in two pieces, he could put in all lower pieces first, making cutouts to match existing ones. Then he put in cellulose insulation, let it settle for a week, and added more before bolting on upper sheets and blowing in the rest of the cellulose. With 16 inches of cellulose at top, 12 inches elsewhere, he got an R-value of 46. To create a secure vapor barrier, Jantzen taped all seams between sheets with aluminum tape. Bridging between shells is gasketed so that no heat is lost through conduction. Wiring and plumbing (polybutylene) are run between the walls of the shells.

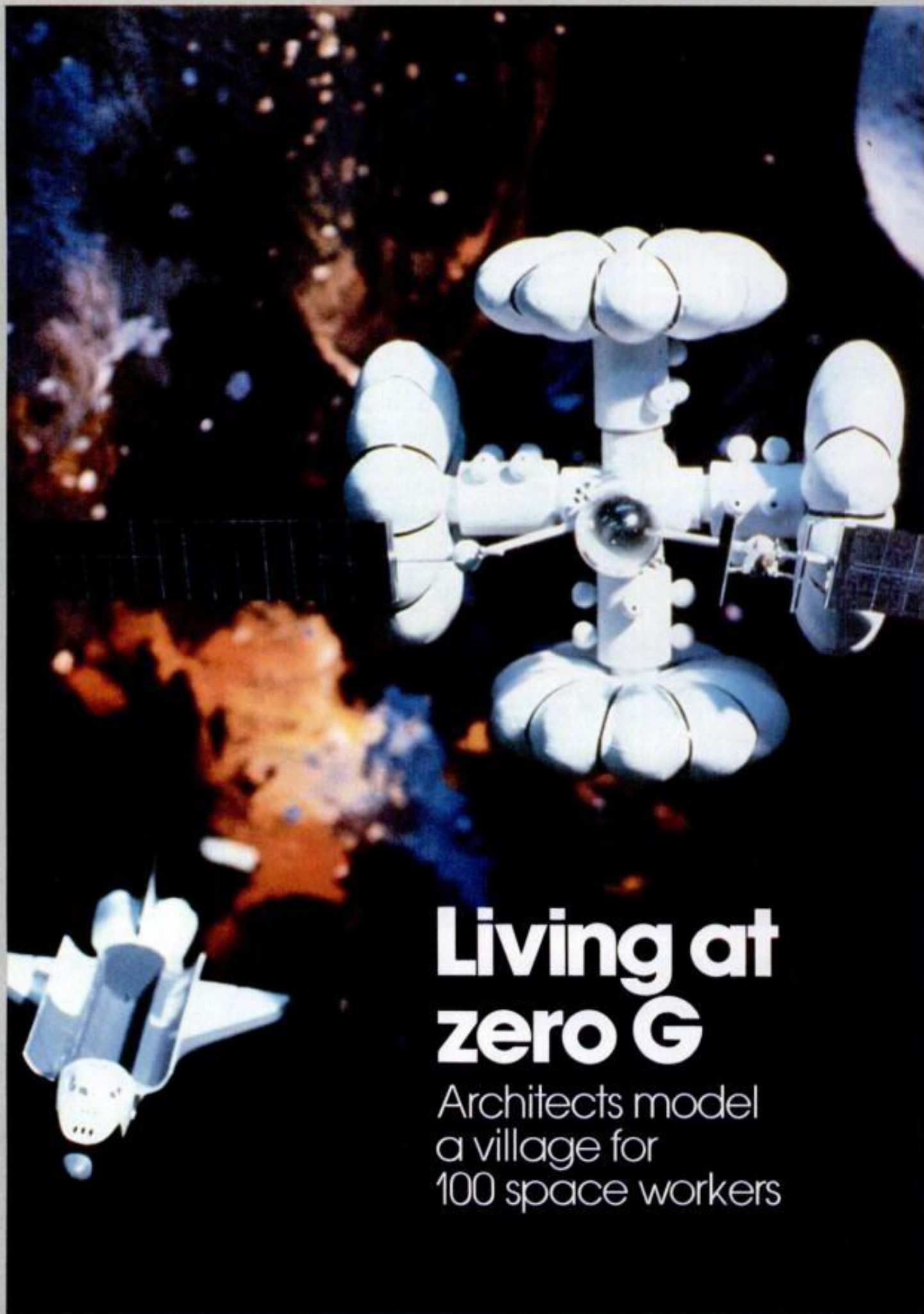


DOMES INTERIOR comes pre-painted, but Jantzen added a 1/2- to 3/4-inch-thick spray-on cellulose coating as an acoustical barrier and painted over that. Windows ended up circular because dome maker had a frame that could be adapted. Glass is double-pane, sealed in car-type gasket. Louvers over windows are opened and closed by string from outside; besides blocking sun, they supply privacy. Arrays of windows (lower photo, facing page) in bedroom and kitchen face generally south. Ventilation in tight house is dealt with by roof vents that exhaust air, and by small openings around house, supplemented by door vents, to admit air. In summer, a

heat exchanger in a well under front deck can be used for cooling. Domes are set directly on concrete slab so earth heat helps to stabilize temperature. Toilet is a Swedish low-flush unit; appliances are high-efficiency types. A built-in dryer over refrigerator uses waste heat to dry fruit; waste heat from oven supplies food warmer. Furniture is all designed and built by Jantzen (with wife Ellen and brother Eric). Top inset photo shows part of bedroom; center photo is living room; bottom is kitchen. Entry structure (top photo, facing page) is double-door airlock made of "chute" sections—which are normally used on the side of a silo.



BUILDING A DOME HOME: Jantzen emphasizes that his dome house is a prototype, still being closely monitored. At press time, it was facing its first winter with five loving (but severe) critics in residence: Jantzen's mother and four sisters. For a manufacturers' list and information about the project and its design philosophy and development, send \$3 to Michael E. Jantzen, Box 217, Carlyle, Ill. 62231. For information about structural aspects, send a stamped, self-addressed envelope to Railoc Co., Inc., 1300 No. Division St., Box 218, Plainfield, Ill. 60544. For a set of blueprints, send \$75 to Railoc.



Living at zero G

Architects model
a village for
100 space workers

Before very long, construction crews will be needed in space. NASA has been wondering how we'll house them

By DANIEL RUBY

PHOTOS BY GUILLERMO TROTTI

In the 25 years since man expanded his horizons beyond planet Earth, space has been the subject of grand explorations and profound scientific discoveries. But, except in communications, its commercial promise has been little exploited. Opportunities for mining, manufacturing, and energy generation in space are unlimited, but such activities will require the presence of workers for extended stays. Where will these space pioneers live, and how will they deal with the problems of life without gravity?

Three years ago, NASA asked a group of researchers from the University of Houston to study these questions and design a space residence for 100 workers. The result is Spacehab, a modular cluster of inflatable pods in which there is no up or down. Photos of the architectural models are displayed on these pages.

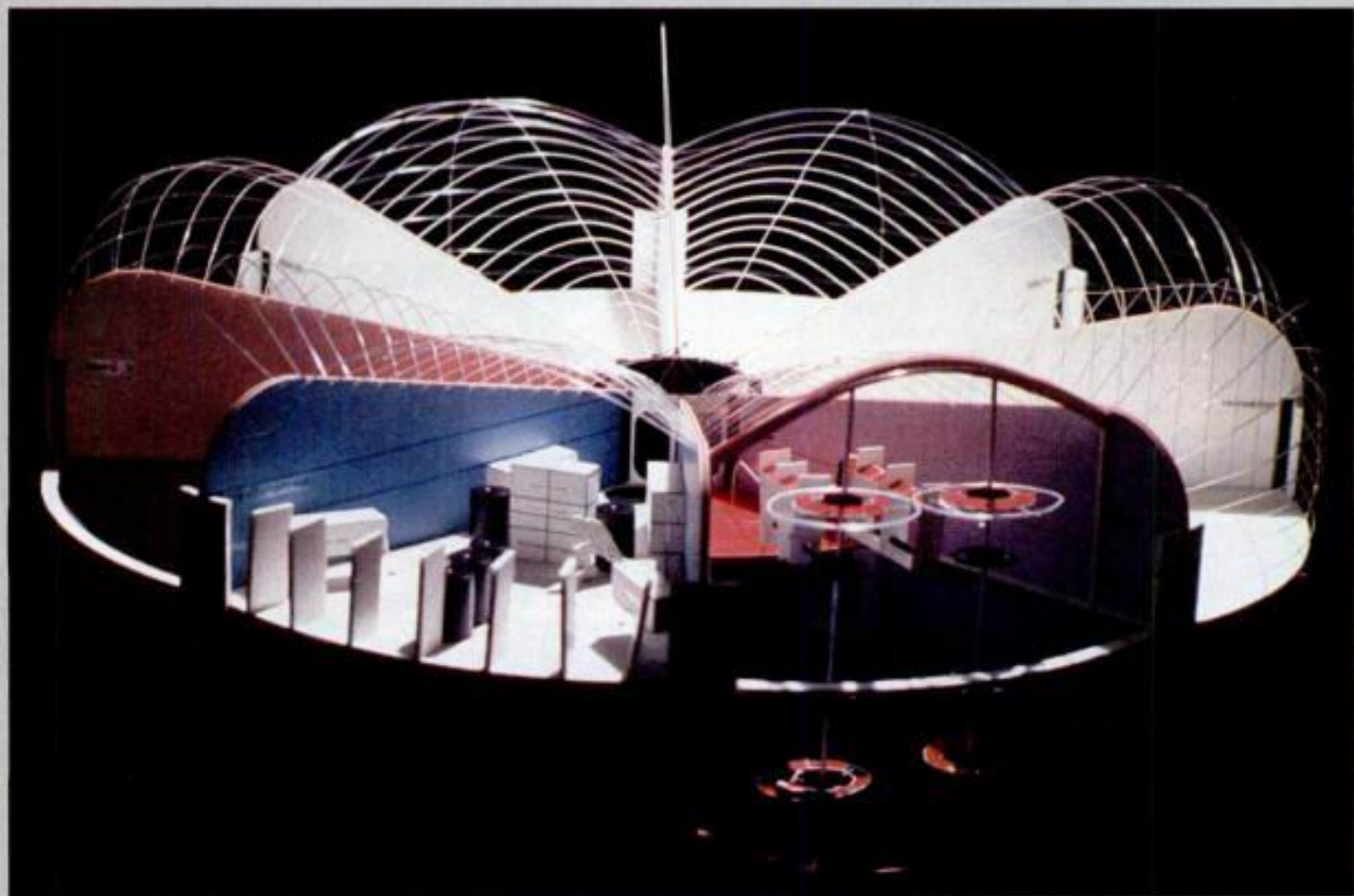
According to architecture professor Larry Bell, who headed the project, microgravity eliminates many traditional design constraints, because "walls, floors, and ceilings are interchangeable." For example, sleeping areas need not be arranged horizontally. Spacehab residents would bed down in sleeping bags attached to the walls of private cubicles. Cubicles could be stacked every which way. Eating would be similarly topsy-turvy. Spacehab's dining room is on two mirror-image levels—without floors or stairs. Diners would simply float in and anchor their trays and feet to circular mounts (photo). For other functions, however, such as sanitary facilities and laboratory tables, it is necessary to simulate gravity with vacuum systems or directional air flows.

Most of the mechanical core of the pods would be assembled on Earth and delivered by space shuttle. The outside membranes—consisting of laminated layers of puncture-, heat-, and radiation-resistant materials—would be inflated in orbit. All of the elements for a full eight-pod station could be delivered in 10 shuttle trips, Bell says. Unlike some other elaborate space colonies that have been proposed, Spacehab is a workable design for the fairly near future. "It doesn't take very much of a commercial operation," Bell says, "before you need 100 or more people living in space."

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Already livable (opposite page), four of Spacehab's eight pods have been delivered by shuttle in this concept. Spheres on connecting modules store volatile materials away from living quarters. Pods consist of split-level, cone-like sections; kitchen and dining areas are pictured below. Design accounts for human needs in a confined environment. Private sleeping cubicles with separate shelves for personal goods (above) would reduce tension among crew. Exercise facilities and electronic audio-visual library would ease boredom.



PROBE IV

Ford's new
wind-cheating
supercar



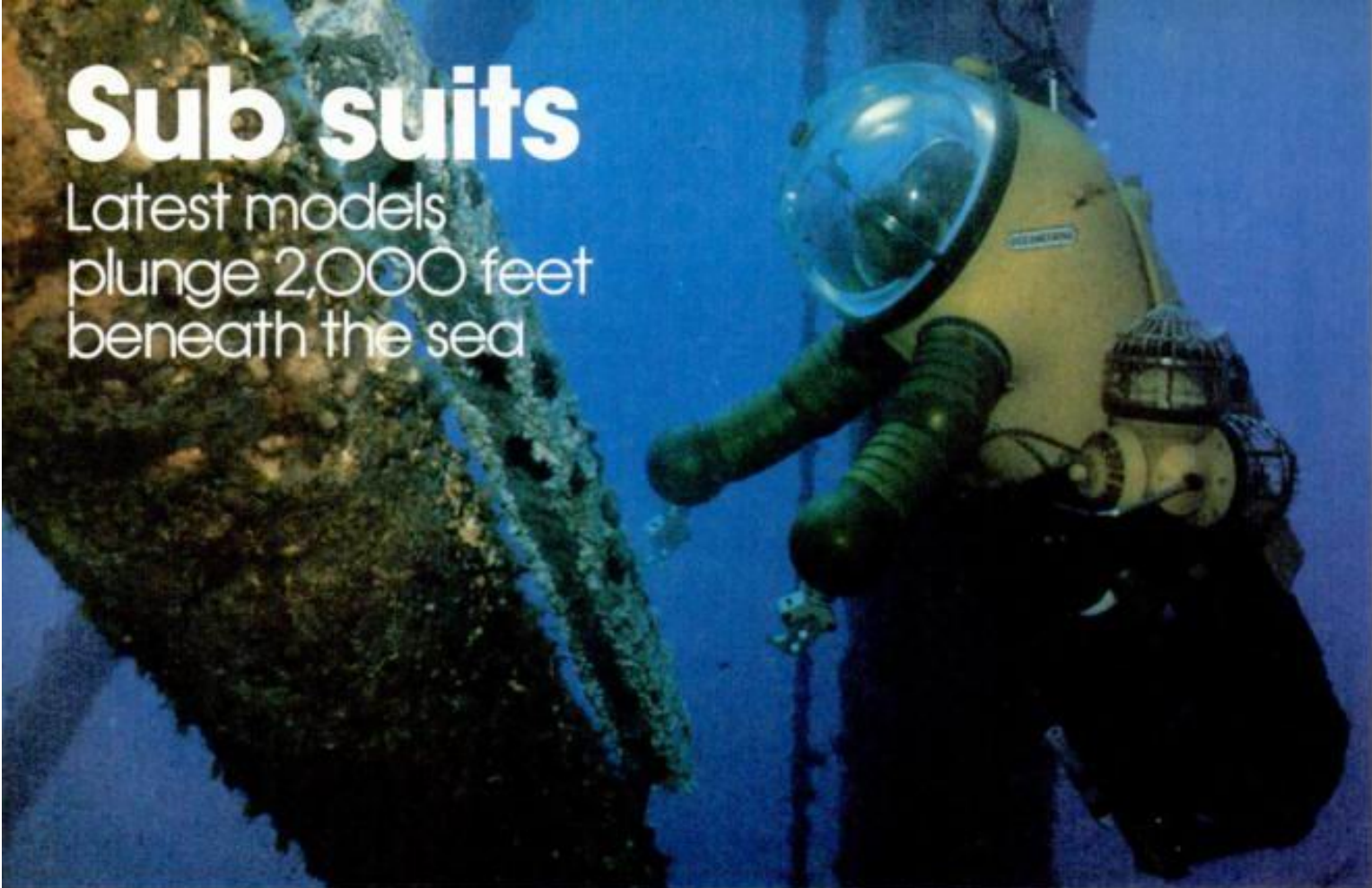
Orbiting dry dock

—nucleus for
a future
space city?



Sub suits

Latest models
plunge 2,000 feet
beneath the sea



Wasp, a legless suit with electrical thrusters for propulsion (top), is named for the insect it resembles. Conceived by Englishman Graham Hawkes, it weighs 1,100 lbs. in air but is neutral in water. Designed for mid-water tasks, the Wasp has lights and a TV camera to transmit images to the surface. The latest Wasp, the Inspector (above), hangs in its deployment cage over a test tank. Nearby is a Jim.

Pressure-proof diving suits, developed for the oil industry, are going to work for science, too

By **CHRISTOPHER SWANN**
PAINTING BY ADOLPH BROTMAN

Encased in a cast-magnesium diving suit known as Jim, I plod step by ponderous step along the bottom of the 37-foot-deep test tank at NASA's National Space Technology Labs in Mississippi. It is like learning to walk all over again. The secret, I am told, is to roll from side to side with a swinging gait. If I want to turn, I am to lean to one side, then lift the opposite foot and put it down in the direction I want to go. Invariably, I end up going

the wrong way. From time to time I adjust the oxygen flow into my oral-nasal mask. Becoming bolder, I lean forward—and promptly fall on my face. To get up, I lean back, arch my legs, and bring the suit upright. But holding the position too long, I fall over backward. I feel as helpless as an overturned turtle. Under instructions from the surface, piped to me through a small loudspeaker in the suit, I grab the handles of my claw-like manipulators and pull myself forward. It works. After 40 minutes in Jim, I can see why it takes 30 hours of tank time to become proficient.

Jim is what the industry calls an atmospheric diving suit, because the operator stays at sea-level atmospheric pressure—14.7 pounds per square inch—no matter how deep he dives.

Continued

Jim has legs and is designed to walk on the ocean bottom (right). Normally it remains tethered to a support ship via lifting and communications cables. In an emergency the operator can jettison the cables, release the lead ballast, and make a buoyant ascent. Then a through-water transducer keeps the operator in touch with the ship. A flashing beacon and pinger aid in recovery. Jim's operator breathes through a mask that doubles as a microphone. Hoses channel his air through chemical scrubbers (in tanks behind his back) where carbon dioxide is removed. Makeup oxygen is fed in from external bottles. Manipulator claws are op-

erated with a T-bar handle. Pushing or pulling the handle opens or closes the jaws, screwing it in or out adjusts the opening, and turning it rotates the claw: (Wasp uses the same manipulators.)

Jim's namesake is Jim Jarratt, a British diver of the '30s who descended to the wreck of the *Lusitania* in an armored diving suit dubbed the Iron Man. Its inventor, Joseph Peress, served as a consultant on Jim. Type II Jim shown is of cast magnesium, weighs 900 lbs. in air, 60 lbs. in water, and is pressure-rated to 1,500 ft. Type III, of aluminum alloy, is rated to 1,000 ft.; and Type IV, made of fiberglass, has the deepest rating—to 2,000 ft.



LIFTING AND
COMMUNICATIONS
CABLES

LIFTING EYE

CO₂-SCRUBBER
VALVE

HATCH-LOCK
HANDLE

ORAL/
NASAL
MASK

PLEXIGLAS
VIEW PORTS

MANIPULATORS

BREATHING
HOSE

FLASHING
BEACON

PRESSURIZED OIL
FOR JOINTS

BATTERY
PACK

LOCATER
PINGER

EMERGENCY
COMMUNICATIONS
TRANSDUCER

500-LITER
OXYGEN
BOTTLES

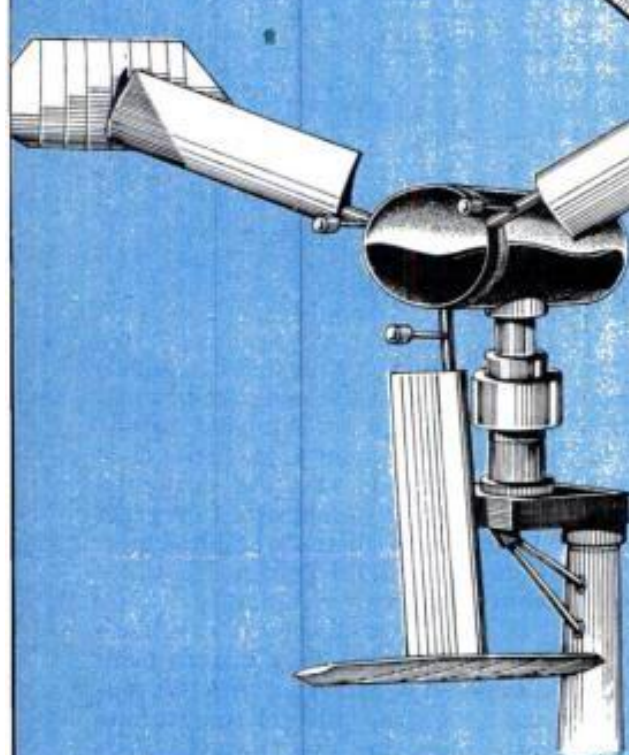
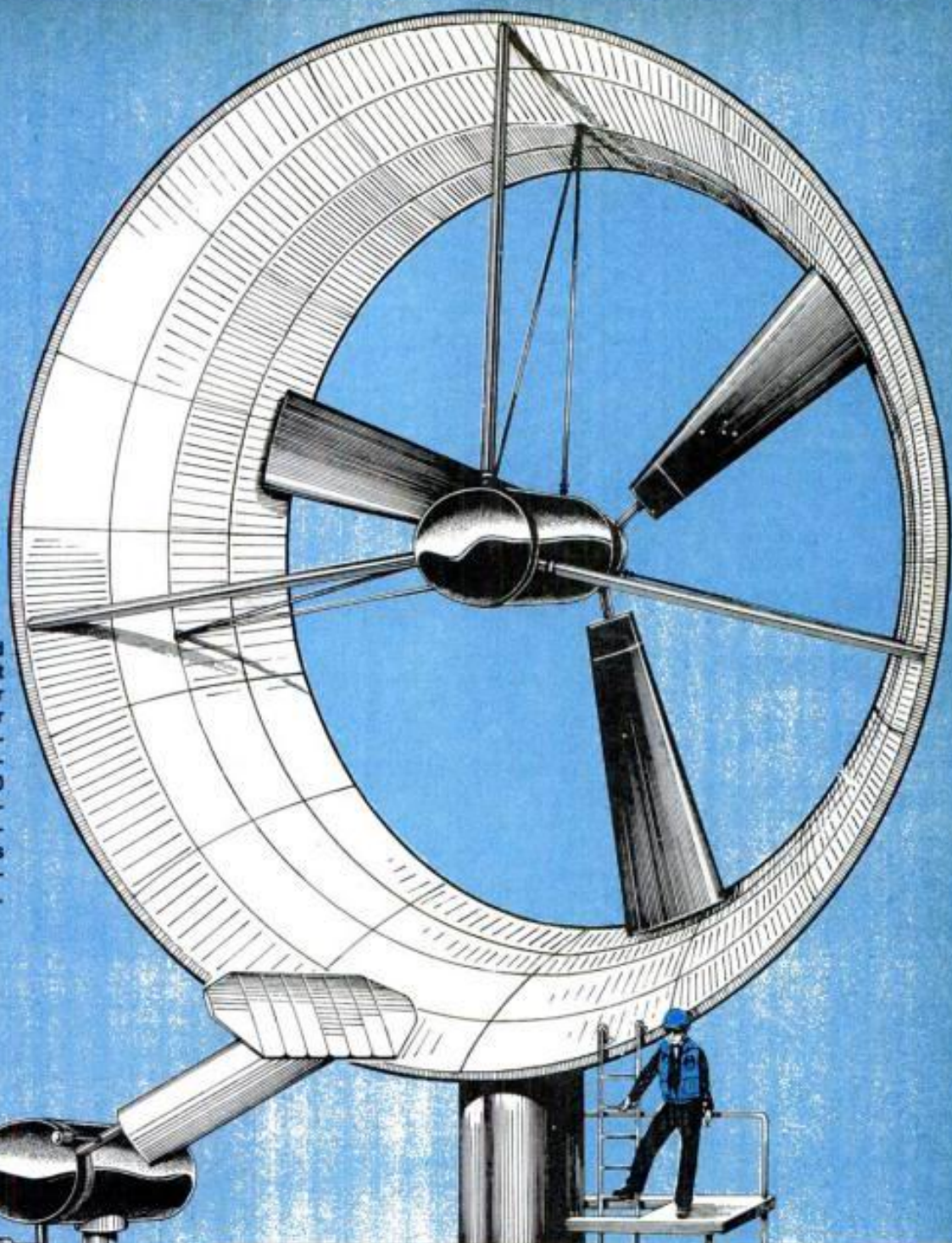
WEIGHTS

PISTON-AND-CYLINDER
JOINT

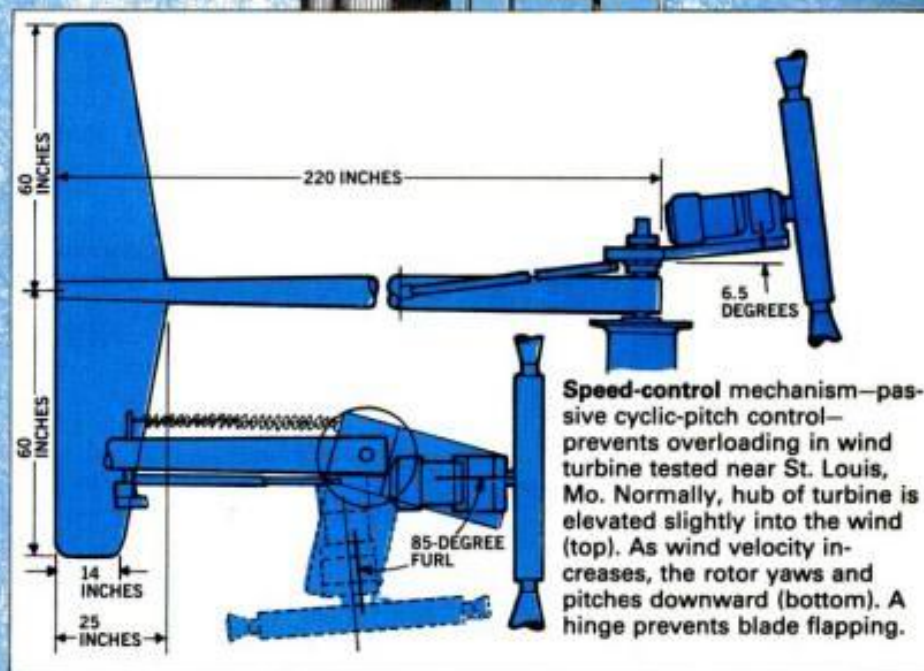
BALL-AND-SOCKET
JOINT

AE BROTMAN

Giant fiberglass shroud could boost power output of large wind turbines over five times, says developer Grumman Aerospace. Diffuser-augmented wind-turbine concept, over 100 years old, creates low-pressure area behind blades, increasing airflow. Artist's concept shows full-size design.

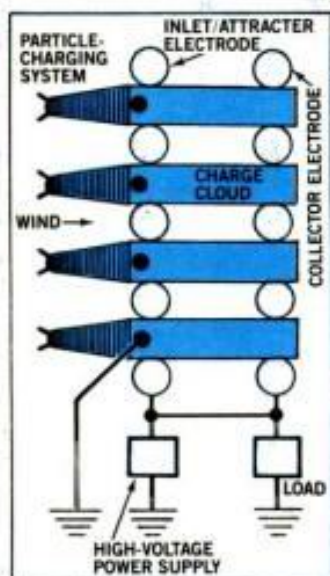


Precision tip vanes at the end of turbine blades can act like the shroud above but with much less complexity. This system, a dynamic inducer tip-vane augments, sets up an air vortex at the end of each blade. Each vortex cancels the vortex behind it, reducing the effects of drag. Smaller, cheaper blades are practical.



Speed-control mechanism—passive cyclic-pitch control—prevents overloading in wind turbine tested near St. Louis, Mo. Normally, hub of turbine is elevated slightly into the wind (top). As wind velocity increases, the rotor yaws and pitches downward (bottom). A hinge prevents blade flapping.

Wind generator with no moving parts is being refined at University of Dayton. The electrofluid dynamic generator, diagramed below, electrically charges water droplets with an attracter electrode. Wind forcing these droplets through collector electrode creates current flow in a load on the electrode.



Vertical-axis wind turbine under study at West Virginia University has circulation-controlled airfoils: Compressed air from an arm holding the blade is pumped out of the trailing edges halfway through each rotation. Exhausted air increases lift and cuts drag on each blade. Efficiency is boosted about 20 percent.

Power output is maintained at a steady level as the blades both pitch and yaw. "At 22-mph wind velocity we're putting out eight kilowatts," said Swift. "At 25 mph we could be putting out more power than the generator could take if we didn't yaw into the wind."

But by yawing and pitching without flapping the blades, the turbine maintains an eight-kilowatt output until wind speed reaches about 50 mph. At that point, the blades are yawed 85 degrees into the wind and power output essentially stops. "That's the storm-survival mode," explained Swift.

Some field testing must still be done. "Our biggest remaining problem is to get the power-on mechanism to work properly to bring the turbine on-line," Swift said. "Remember,

we're still in the research phase."

Diffuser-augmented wind turbine. Can a standard wind turbine's performance be significantly improved to produce more energy? One system nearing completion at Grumman Aerospace Corp. in Bethpage, N.Y., does exactly that. Grumman's diffuser-augmented wind turbine has been under development since 1973.

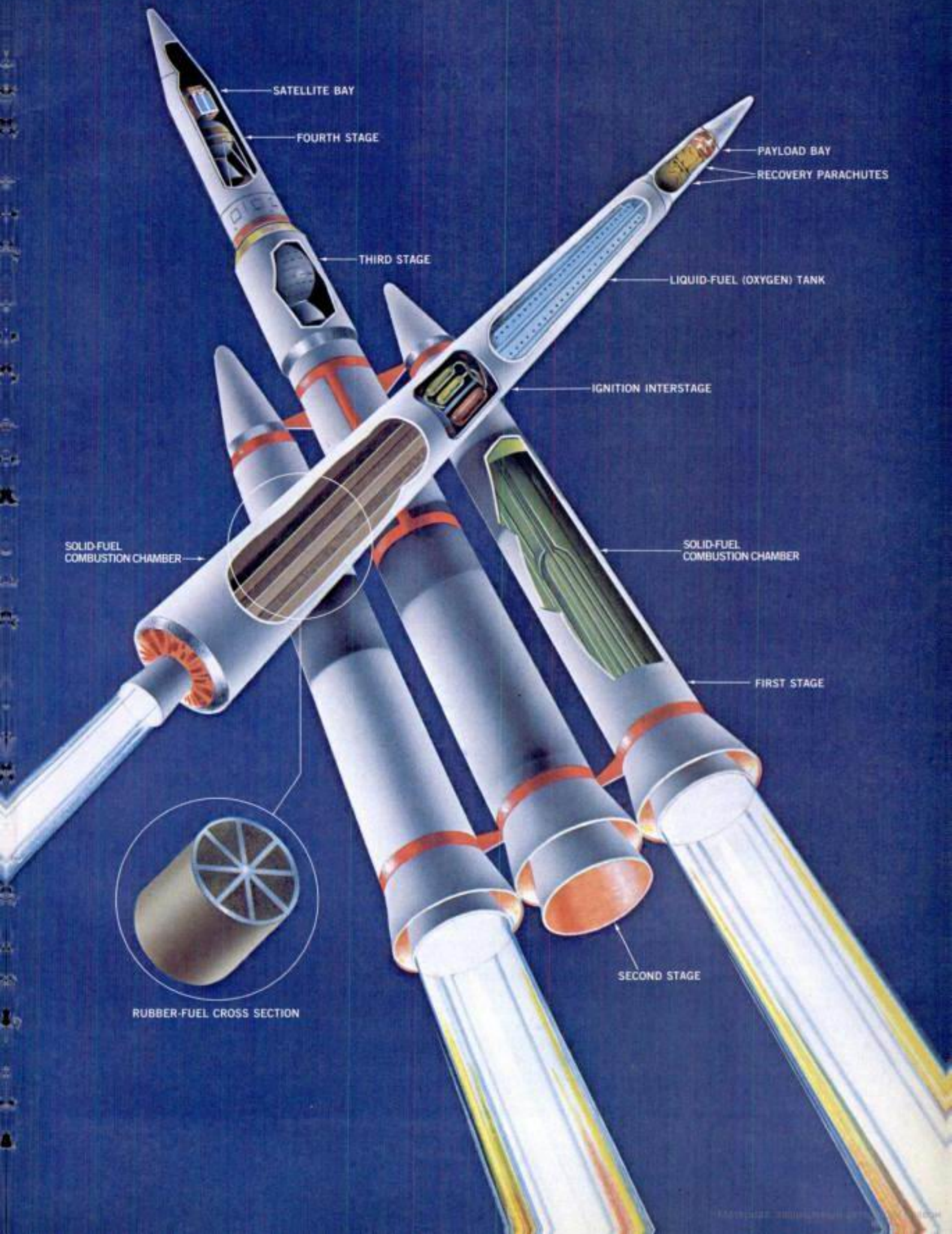
The concept is simple: Mount the turbine inside a squat, funnel-like shroud with the turbine blades rotating close to the narrow end. Then point that narrow end into the wind. As air flows past the turbine blades, the shroud widens and the moving air diffuses into this larger space. The result is a low-pressure area directly behind the blades. That sucks more air into the shroud, sharply increasing airflow over the blades.

Comparing turbines with equal-size blades, Grumman wind-tunnel tests showed that a shrouded turbine produced four times as much power as an unshrouded model. Full-scale turbines should do even better. Program manager Ken Foreman believes larger turbines could deliver 5.5 times more power with a shroud.

SERI's Mitchell gave Grumman's work high marks. "Significantly more energy can be extracted with this concept than with a conventional turbine of the same size," he reported.

But achieving shroud designs with this potential was hard work. The shroud design evolved through a number of steps as engineers faced difficult questions:

- How to build a shroud that would be strong and relatively inexpensive.
- How to correct the airflow prob-



SATELLITE BAY

FOURTH STAGE

THIRD STAGE

PAYLOAD BAY

RECOVERY PARACHUTES

LIQUID-FUEL (OXYGEN) TANK

IGNITION INTERSTAGE

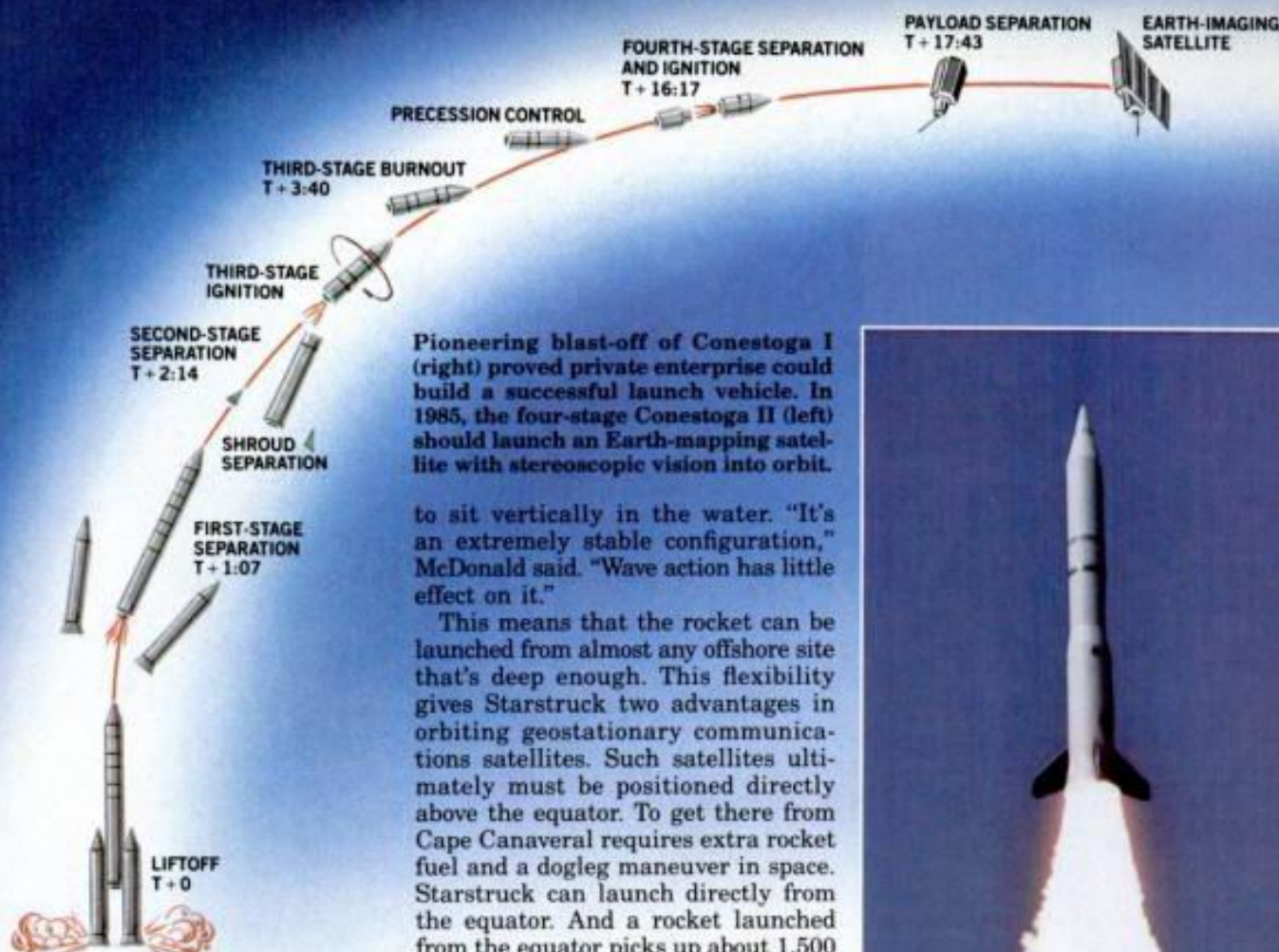
SOLID-FUEL
COMBUSTION CHAMBER

SOLID-FUEL
COMBUSTION CHAMBER

FIRST STAGE

SECOND STAGE

RUBBER-FUEL CROSS SECTION



Pioneering blast-off of Conestoga I (right) proved private enterprise could build a successful launch vehicle. In 1985, the four-stage Conestoga II (left) should launch an Earth-mapping satellite with stereoscopic vision into orbit.

to sit vertically in the water. "It's an extremely stable configuration," McDonald said. "Wave action has little effect on it."

This means that the rocket can be launched from almost any offshore site that's deep enough. This flexibility gives Starstruck two advantages in orbiting geostationary communications satellites. Such satellites ultimately must be positioned directly above the equator. To get there from Cape Canaveral requires extra rocket fuel and a dogleg maneuver in space. Starstruck can launch directly from the equator. And a rocket launched from the equator picks up about 1,500 feet per second in velocity from Earth's rotation. This further reduces the propulsion force needed to reach orbit.

The net effect is to sharply reduce launch costs. McDonald expects Starstruck to put communications satellites into orbit for slightly more than \$20 million, two-thirds the fee currently charged by NASA and Ariane-space, the European launch agency [PS, July '80].

Reduced risks

Starstruck engineers think their hybrid motor—it uses liquid oxygen in combination with a solid fuel—reduces the potential for disaster.

"The hybrid engine eliminates the kind of explosive failure modes you see with either liquid or solid propellants used alone," McDonald said.

The rocket takes advantage of the best characteristics of both types of propellants. Polybutadiene mixed with epoxy is poured directly into a fuel tank, flowing around removable vertical molds, which creates open channels, or fuel ports. The result is a uniform fuel structure that looks and feels like tire rubber.

The fuel is safe. "You could hold a match to it without igniting it," McDonald pointed out. "The casting process also is a safety factor. Most solid-rocket explosions are caused by a crack in the fuel that allows a flame



barrier not intended to create "clean-room" conditions—McDonald skirted Dolphin's electrical-equipment bay and pointed to an ancient Army-surplus missile-tracking trailer. "This thing looks like something out of an old science-fiction movie," he said with a grin. "That antenna up there just goes around and around."

This antique system, once loaded on a boat and taken to sea, would serve as Starstruck's primary tracking station, McDonald told me.

"We're not investing in expensive launch facilities," McDonald said. "And by using water-launch technology, we avoid all the problems involved with getting government permits."

Water-launching rockets is not a new technique, McDonald explained. "The U.S. Navy perfected the technology more than 20 years ago," he said as we dodged sparks from a welder's torch. But the Navy later chose the more-convenient use of submarines as undersea launch pads.

Today, Starstruck is convinced that water-launching holds great commercial potential. In addition to eliminating millions of dollars in front-end expense, the technique gives the company almost complete freedom in selecting launch sites.

With most of its weight at the bottom, the rocket is ballasted and stabilized

INVISIBLE SUBS

Fiber-optic acoustic sensors, rare-earth low-frequency transducers, artificial-intelligence systems, wake and radioactive-trace detectors, and space-based lasers—these are some of the devices on the horizon that may turn the oceans transparent to sub hunters. For now, however, with sonar as the only available means of detection, super-quiet submarines, aided by the unpredictability of underwater acoustics, remain near-invisible.

PAINTING BY DEAN ELLIS



Материал, защищенный авторским правом

By RICHARD LAYNE

Research assistant: Julie Hauptman

There's an old saying around the Navy that goes like this: "There's two kinds of ships in the world—subs and targets."

It's partially true. In the global game of hide-and-seek between submarines and sub hunters, it's the latter that come out losers. Writing in the August 1984 *U.S. Naval Institute Proceedings*, Hamlin A. Caldwell Jr., formerly with the Naval Underwater Systems Center, says, "If we have learned one thing about ASW [anti-submarine warfare], it is that given sea room and time, a sub is virtually undetectable." The reason for this stealth? The peculiarities of underwater acoustics; a sub's ability to live up to the nickname, "the silent service"; and the limitations of the primary means of detection, sonar (short for sound navigation and ranging).

Despite its handicaps, sonar's continuing role is virtually guaranteed by the nature of underwater phenomena. Writing in the January 1985 *U.S. Naval Institute Pro-*

Continued

Submarine hunting in the future will use today's platforms to carry ultra-sensitive acoustic and non-acoustic detectors. First detection of an enemy submarine might come from anchored sonobuoys, part of the Navy's hush-hush moored surveillance system, or from space-based deep-blue lasers or satellites capable of pinpointing the wake of a deep-running sub. These detectors communicate with shore-based stations, which would warn a carrier group's first line of defense: a destroyer towing an 800-ft. array of fiber-optic hydrophones. If passive sonar fails, ships can try active sonar and bounce a series of pings off the ocean's bottom. This "bottom bounce" method—backed by high-powered deciphering computers—can locate a submarine, but it also alerts the sub to the presence of unfriendly pursuers. Swift, evasive maneuvers cause a concurrent increase in radiated noise that can be heard by sonobuoys, which are dropped by airplane in a pattern around a sub's probable bearing. Sonobuoys parachute down; when they hit the water, a transmitter stays afloat and a tethered sonar capsule sinks to a predetermined depth. The most mobile and effective sub-hunting platform is a submarine equipped with passive sonar and low-frequency rare-earth transducers, immune to countermeasures. Helicopters use active sonar to comb deep water, where sound carries farthest.



wingsail



Tanker model is outfitted with two tri-plane wingsails. Upwind trim vanes ahead of mast are auxiliary steering aids considered in early design con-

cepts. These have been dropped, as tail fins were found sufficient. White form behind model is actual 44-ft. wing section being built for 3,000-ton freighter.

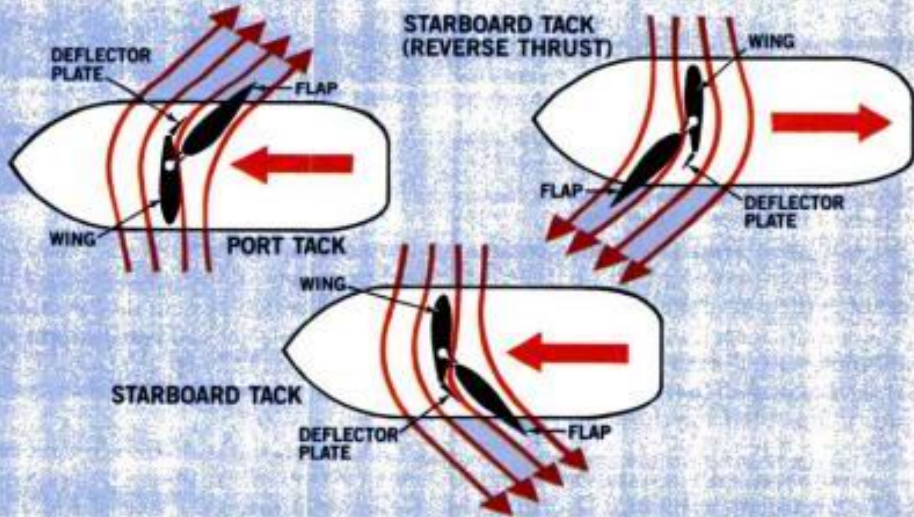


Trials of wingsail concept were conducted on *Flyer*, a 34-ft. hydrofoil.



Walker's latest wingsail model has arrowhead end plates on wings to limit wind spill from airfoils. Probe carries wind-speed and -direction sensors.

Wingsail is steered by powered tail fin (omitted for clarity) under computer control, giving fine adjustment and speedy response to shifts in wind direction. As on an airplane, wing's leading edge always heads into the wind. Large flap, adding more thrust, is hydraulically angled behind wing section at 45 deg. on either side, depending on port or starboard tack. When tack changes and powered flap pivots across, hinged deflector plate wipes over flap nose to its same fixed angle on the opposite side. Airfoil sail provides drive around 345-deg. arc. It has a lift coefficient of 2.5 versus 0.9 for rival Japanese designs. For reverse thrust to reduce stopping distance, flap alone is swung to mirror-image position for given tack. That directs wind force ahead.



A manned base on the

Establishing a permanent moon base would be a daunting engineering challenge, but experts say it can be done. Proponents point out that the moon is an outstanding location for astronomical studies, an abundant source of raw materials, and a possible stepping stone to other planets. Others ask whether the effort is worth the price.

By JIM SCHEFTER

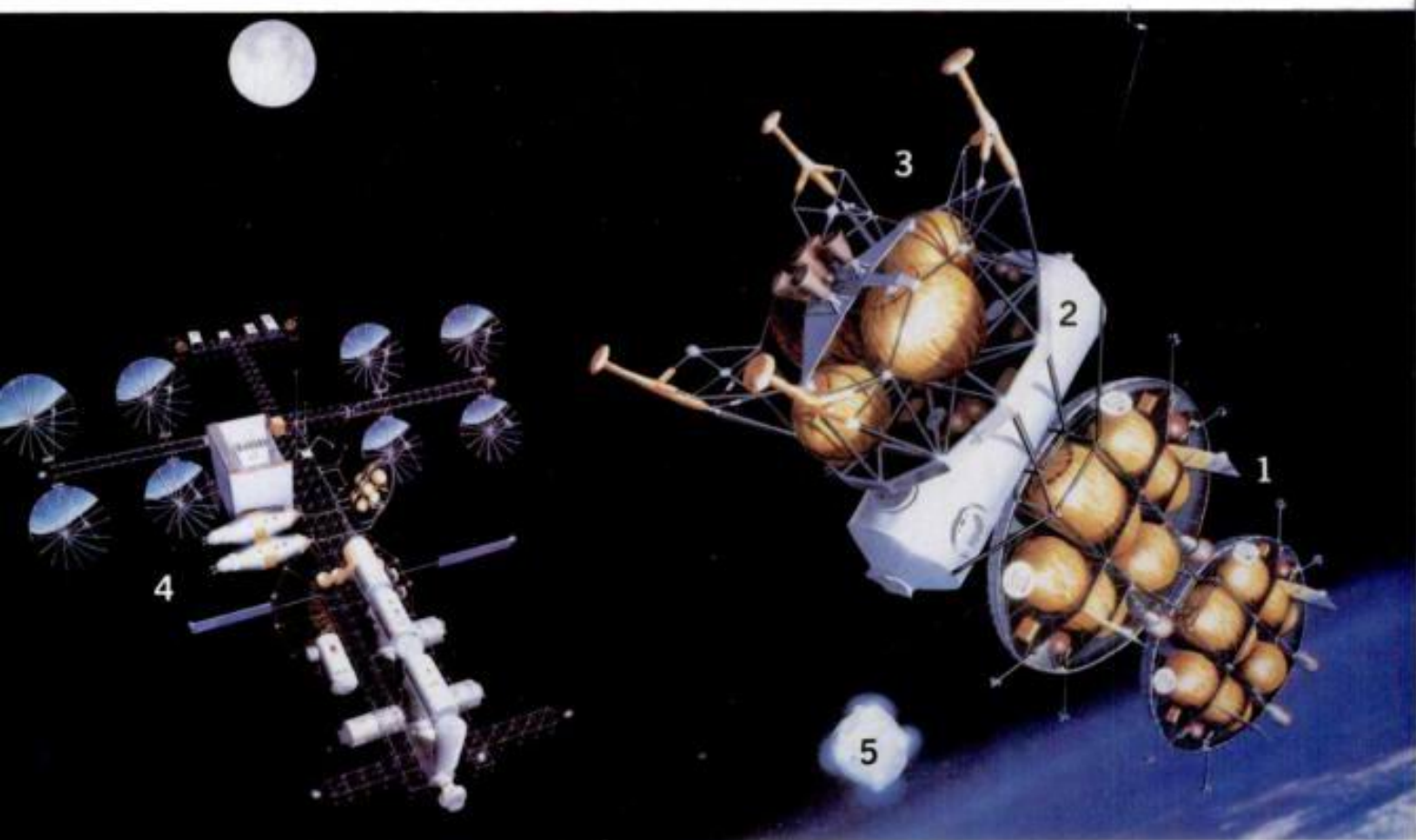
At the Johnson Space Center in Houston, two highly regarded space experts spearhead a grass-roots campaign to turn the nation's thoughts toward carving out a fresh foothold on the moon.

In Albuquerque, N.M., a leading American scientist—the only one who has walked on the moon—proposes the Millennium Project, a Mars expedition early in the 21st century that would use the moon as a training base.

At major gatherings in La Jolla, Calif., Los Alamos, N.M., and Washington, D.C., packed meeting rooms are the scenes of impassioned, and sometimes heated, discussions aimed at a single long-range goal: establishing a permanent manned base on the moon.

With the U.S. committed to putting a permanent station in orbit around Earth in the next seven years (PS, Feb.), the pressure is building to look ahead to the 21st century—to go back to the moon, not just for a quick visit,

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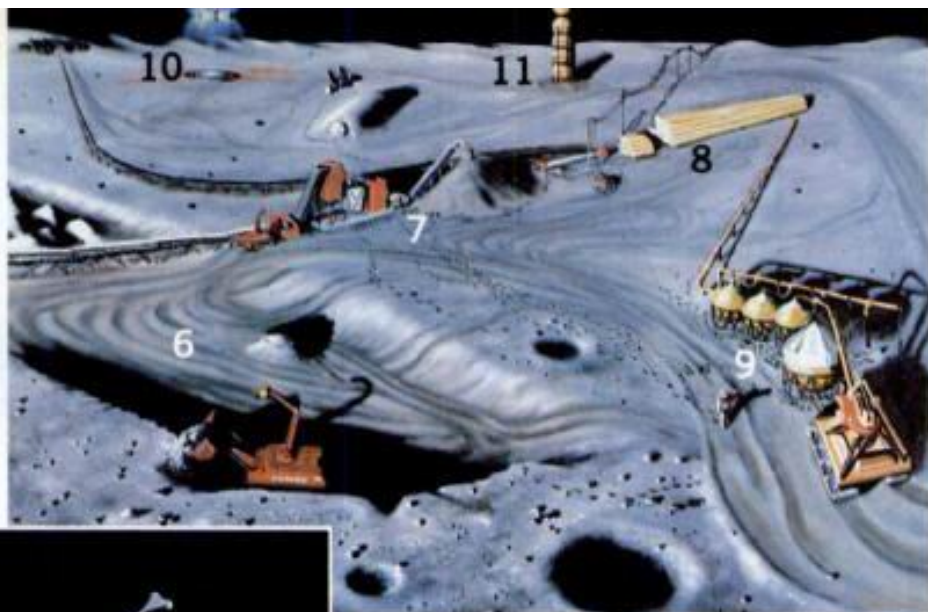


The first step in building a moon base would be to set up habitats and laboratories. These probably would be modified space-station modules. Here two

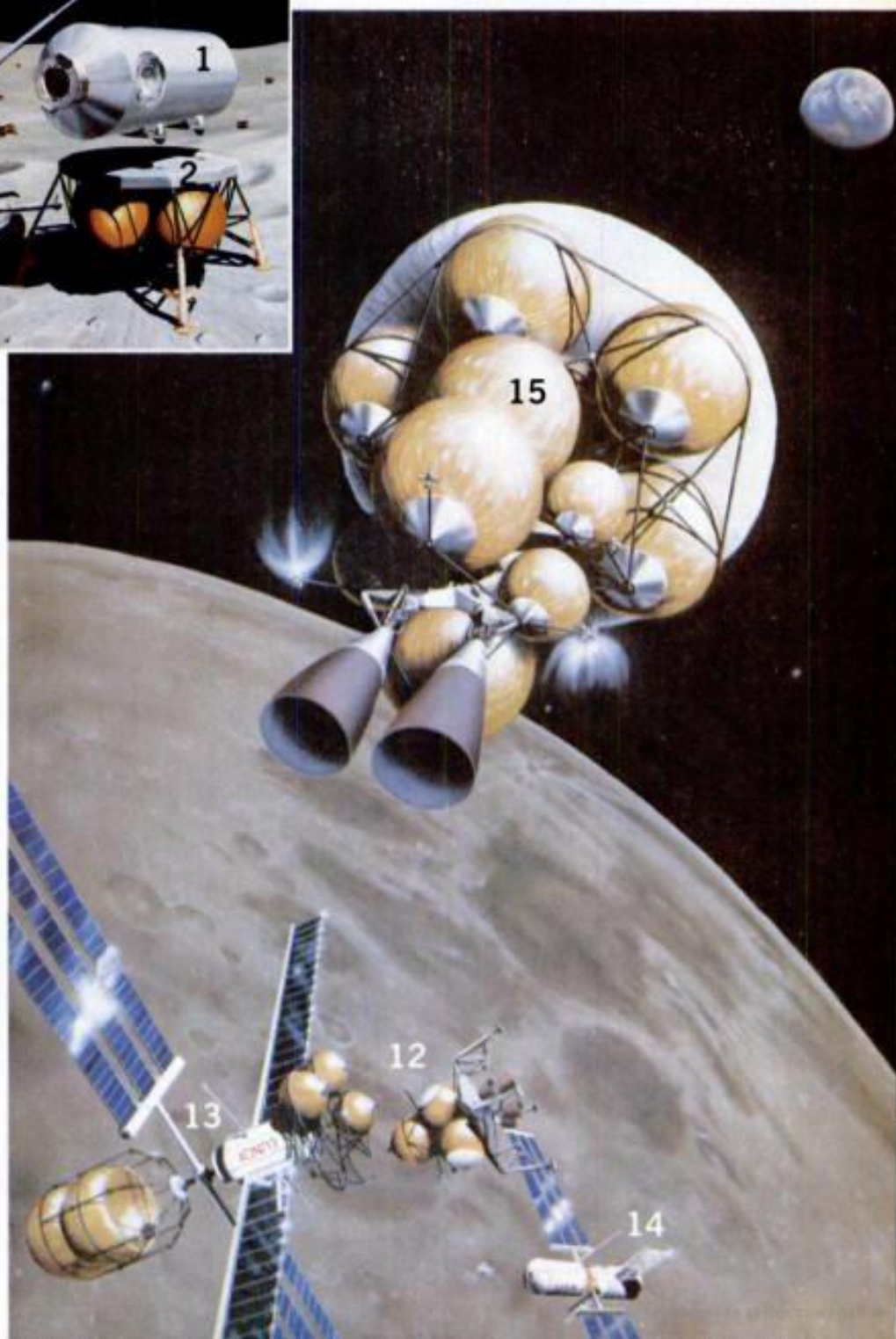
orbital transfer vehicles (OTVs) (1) are preparing to take a module (2) and its descent stage (3) from the low-Earth-orbit space station (4) to the moon. The

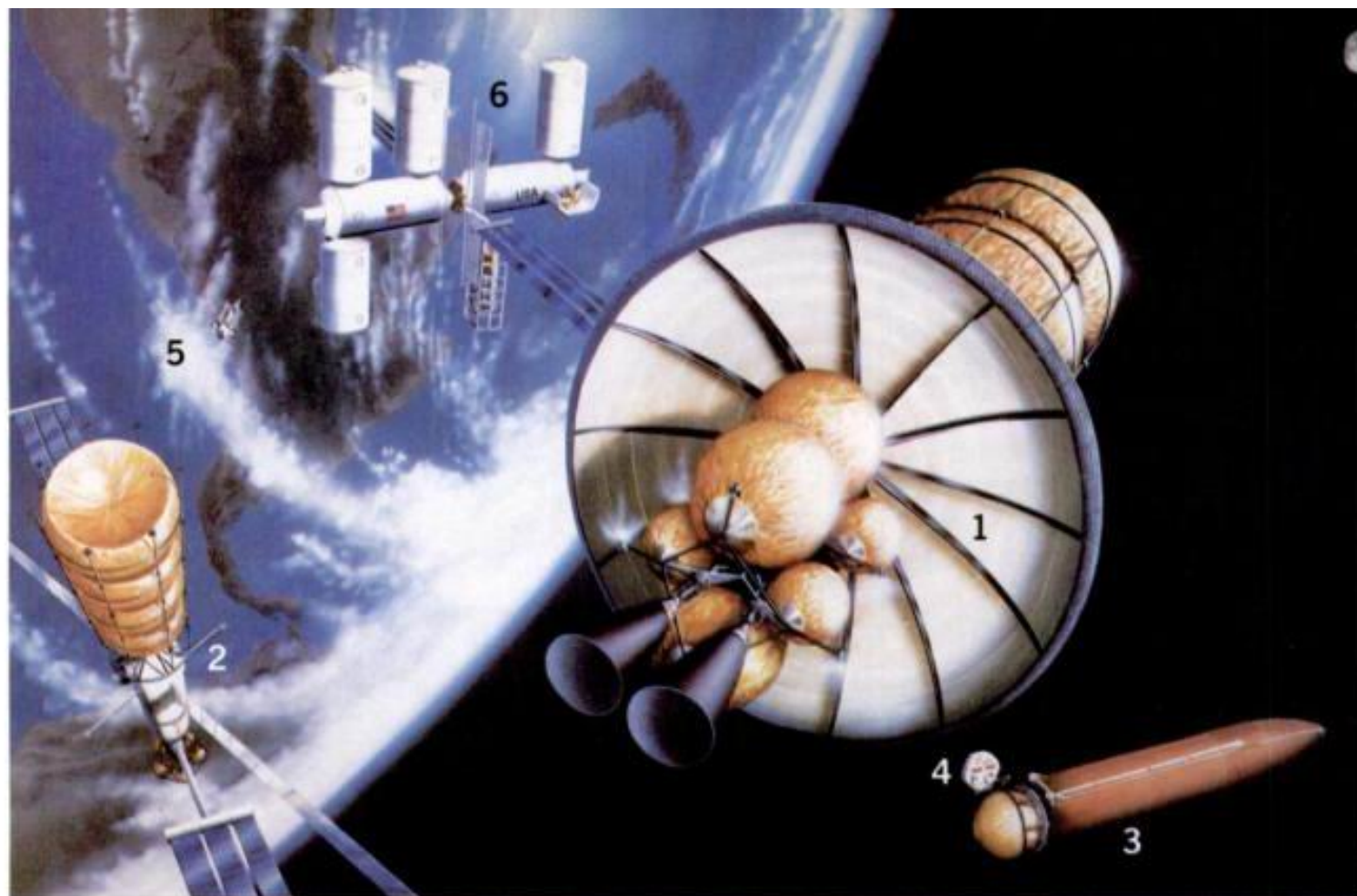
OTVs will return to the space station. A robotic cargo handler (5), operated from the space station, is leaving the OTVs and returning to home base.

moon?



On the moon (above), a laboratory/habitat module (1) is hoisted from its descent stage (2) by a mobile crane (3), which will transport it to the moon base (4). There it will be buried to shield the inhabitants from solar radiation. Inverted cones (5) are thermal radiators of a nuclear power plant. Top: Liquid-oxygen production, the chief industry of the now-established moon base, begins with a strip mine (6), where front-end loaders dig out soil. They deliver it to an automated plant (7), where the mineral ilmenite (FeTiO_3) is separated out, then chemically reduced by heating in the presence of hydrogen. Products of the reaction are iron, titanium oxide, and water. Some water is piped to an electrolysis facility (8), where the hydrogen and oxygen are separated. The oxygen is liquefied and stored in spherical tanks (9). One such tank is being hoisted for delivery to a lunar ferry (10), now descending, which will transport it to a propellant storage depot in lunar orbit. In the center sits a stack of hydrogen tanks (11) imported from Earth. Power lines stretch over the ridge to a nuclear power station. Right: The lunar ferry (12) delivers its load of liquid oxygen from the moon base to the propellant storage depot (13). On the other end of the depot are two hydrogen tanks brought from Earth. A small space station (14) is above the depot. A lunar freighter (15) is loaded with oxygen tanks. The large heat shield in front helps to slow the freighter as it enters Earth orbit.





Earth-orbiting lunar freighter (1), loaded with hydrogen tanks exported from Earth, is about to embark for the moon. An Earth-orbiting propellant storage depot (2) stores hydrogen tanks on one end and oxygen tanks on the

other. Another storage facility for hydrogen is the shuttle's external tank (3), now the only part of the shuttle that's not reused (it's jettisoned into the Indian Ocean). In this concept it would be boosted into orbit, and hydrogen

tanks delivered from Earth would be attached to the rear. Here the robotic cargo handler (4) has just been used to attach a hydrogen tank. A space shuttle (5) and the low-Earth-orbit space station (6) are seen in the rear.

but to stay. The nation's space experts agree that it can be done, and some are already sketching the outlines for what could be the greatest engineering challenge ever.

Would it be worth the price? Some say no. But moon-base backers are marshaling their arguments: most important, they say, is that the moon could become economically self-supporting by supplying raw materials to the space station. And it could do much more. "A lunar base gives the operational experience you need before you can colonize the planets," said astronomer Wendell Mendell of Johnson Space Center's Solar System Exploration Division. "It's a site for studying Earth and the sun, and for astronomy." Finally, it's a base for studying the moon itself—still mysterious despite six excursions by Apollo astronauts across its desolate surface.

Pros and cons

Like every multibillion-dollar government project, the moon-base concept draws opponents. "It would be tunnel vision to say that a moon base is the goal after a space station," said Jesco von Puttkamer, a long-range planner at NASA headquarters in Washington. "Going back to the moon is just one option we're looking at."

Famed space scientist Dr. James Van Allen is lukewarm to the idea, calling it "cheese in the sky." And astronomer Carl Sagan fears that funding a lunar colony would delay any expedition to Mars, which he considers more important.

Dr. Harrison H. (Jack) Schmitt disagrees. Geologist and former U.S. Senator from New Mexico, Schmitt walked on the moon as an Apollo astronaut in 1972. He now writes and lectures widely, serves on several presidential advisory boards, and is actively pushing for the U.S. to spear-

head an international project to land astronauts on Mars early in the next century. He calls it the Millennium Project, and sees a moon base as an ideal training ground. "It's a stepping stone to Mars," he told me. The Millennium Ship would be assembled at the space station and launched from there on a two-year round trip that would include putting a party of explorers on the Martian surface for 30 days. "A moon base could give us the experience we need to live on another planet," he said.

"It's the next step on the frontier," agreed Mendell, who puts the date for the first lunar settlement at about 2007.

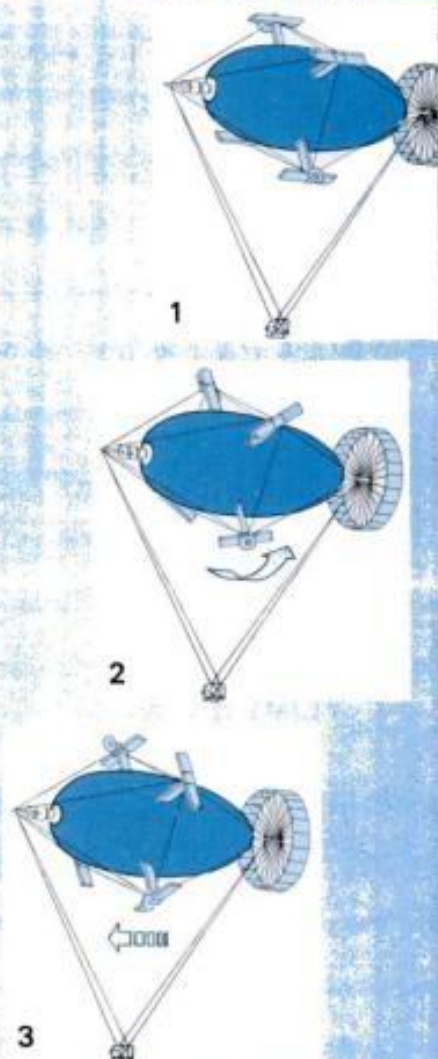
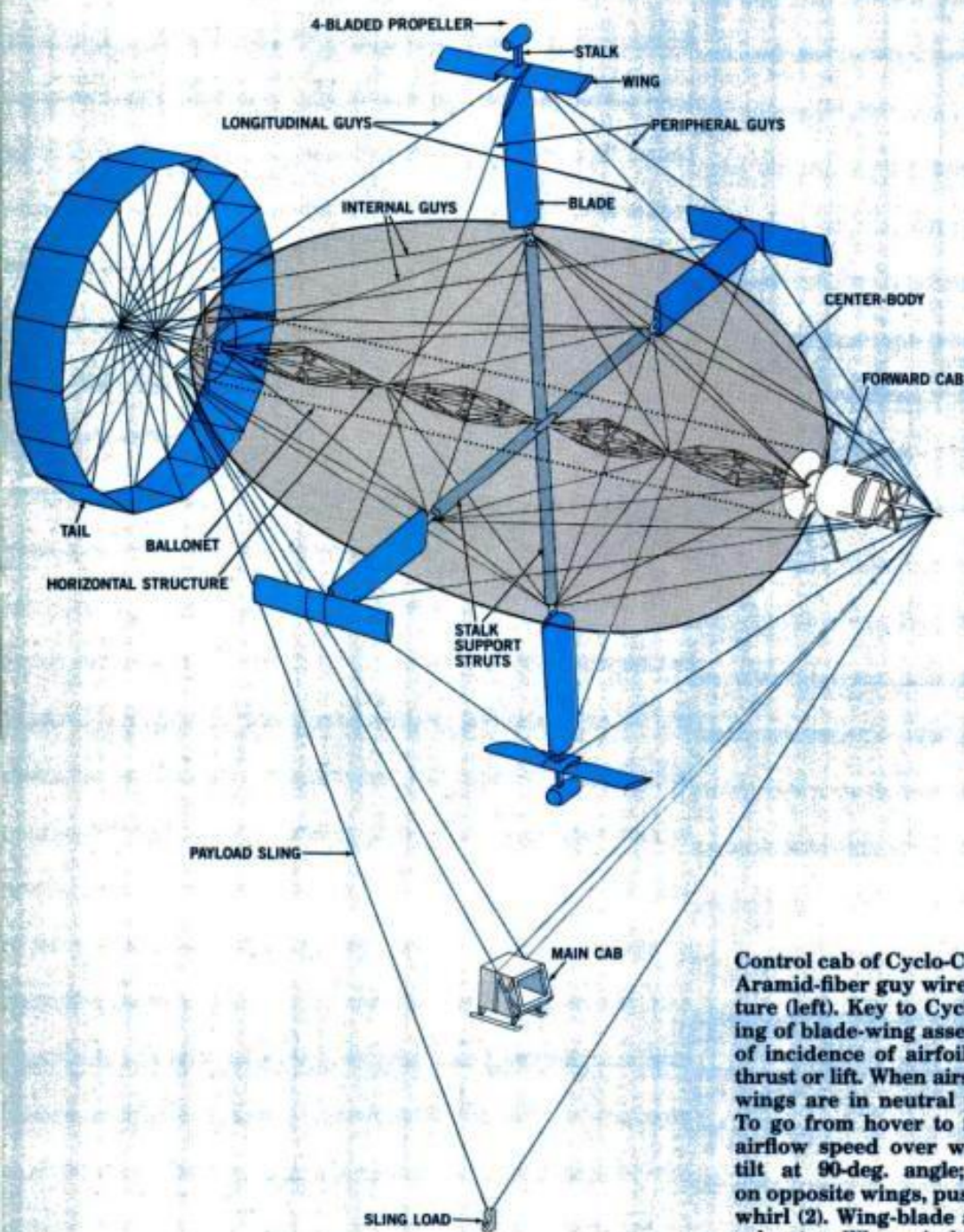
NASA is not ready to take an official position on either a moon base or the Millennium Project. But it did convene a three-day scientific symposium in Washington last October to hear scores of reports favoring a lunar base. More than 300 people participated, all influential in science, engineering, and aerospace.

NASA's meeting built on recommendations from two sources: a lunar-base working group convened by both the space agency and the University of California's Institute of Geophysics and Planetary Physics at Los Alamos earlier in 1984 (PS, May), and a 10-week summer workshop at the California Space Institute in La Jolla. Both sessions concluded that a moon base could help meet important space-exploration goals early next century.

Instruments placed permanently on the moon could open new and exciting windows on space research, according to Los Alamos physicist Paul Keaton. Seismometers, heat-flow sensors, and other instruments would fill in the gaps Apollo's brief forays left in understanding the moon's crust and mineral resources. Astronomical observations would be free of distortions generated by Earth's atmosphere.

Whirling airship

This 178-foot-long lighter-than-air vessel represents a new concept in flying: It gets lift and thrust by spinning on its horizontal axis. The highly maneuverable aircraft may be used for military missions or to haul multi-ton loads of lumber. A prototype was destroyed in 1982, but a new version is now flying—and lifting.



Control cab of Cyclo-Crane is suspended below center-body. Aramid-fiber guy wires secure internal and external structure (left). Key to Cyclo-Crane's aerodynamics is positioning of blade-wing assembly. Cyclical control changes angle of incidence of airfoils as they rotate to provide desired thrust or lift. When airship is hovering (1), variable-incidence wings are in neutral position, parallel to horizontal axis. To go from hover to flight, center-body spins to increase airflow speed over wings. Blades swivel, and propellers tilt at 90-deg. angle; two 150-hp reciprocating engines, on opposite wings, push center-body into counterclockwise whirl (2). Wing-blade assembly adjusts as Cyclo-Crane accelerates. When airship reaches maximum speed, it stops rotating (3). Blades and engines align with direction of flight; wings provide lift like an airplane's.

By BEN KOCIVAR

Drawings by Walter Hortens

If Cyclo-Crane isn't the world's strangest flying machine, it's certainly a prime candidate for the title. The complex hybrid combines the technologies of a blimp, dirigible, helicopter, and airplane in ways that would make Rube Goldberg fans green with envy—and gray with trepidation.

The proof-of-concept load-lifting airship, developed by Arthur Crimmins, co-founder of AeroLift (4105 Blimp Blvd., Tillamook, Ore. 97141) does something totally new in the history of flight: It spins on its horizontal axis to supply lift and thrust, giving it the maneuverability of a helicopter. When it reaches full forward speed, the whirling stops, the wings and blades adjust, and the craft flies like an airplane. Its most-likely missions: airlifting difficult-to-retrieve timber, and military surveillance and transport.

"Cyclo-Crane has neutral buoyancy," says AeroLift's Willard Haunschild. "The helium-filled center-body lifts the entire structure and supplies half the lift for the sling load." The balance of lift and all the thrust and control come from the engines and the alignment of the four wing-and-blade assemblies. Cyclo-Crane spins counter-clockwise (see trail of streamers in photo) to increase the airflow over these assemblies. The faster the airflow, the more potential lift and thrust. By varying the pitch of the blades and wings, a pilot can propel the semirigid airship up, down, sideways, forward, or backward.

The multi-faceted, ring-shaped tail serves no function in flight but does stabilize the craft when it's moored to an outdoor mast on a single tether. The tail is an improvement over a Y-shaped predecessor on the first Cyclo-Crane. That 138-foot version was built in 1982 and destroyed the same year by a storm while tethered outside its Tillamook hangar.

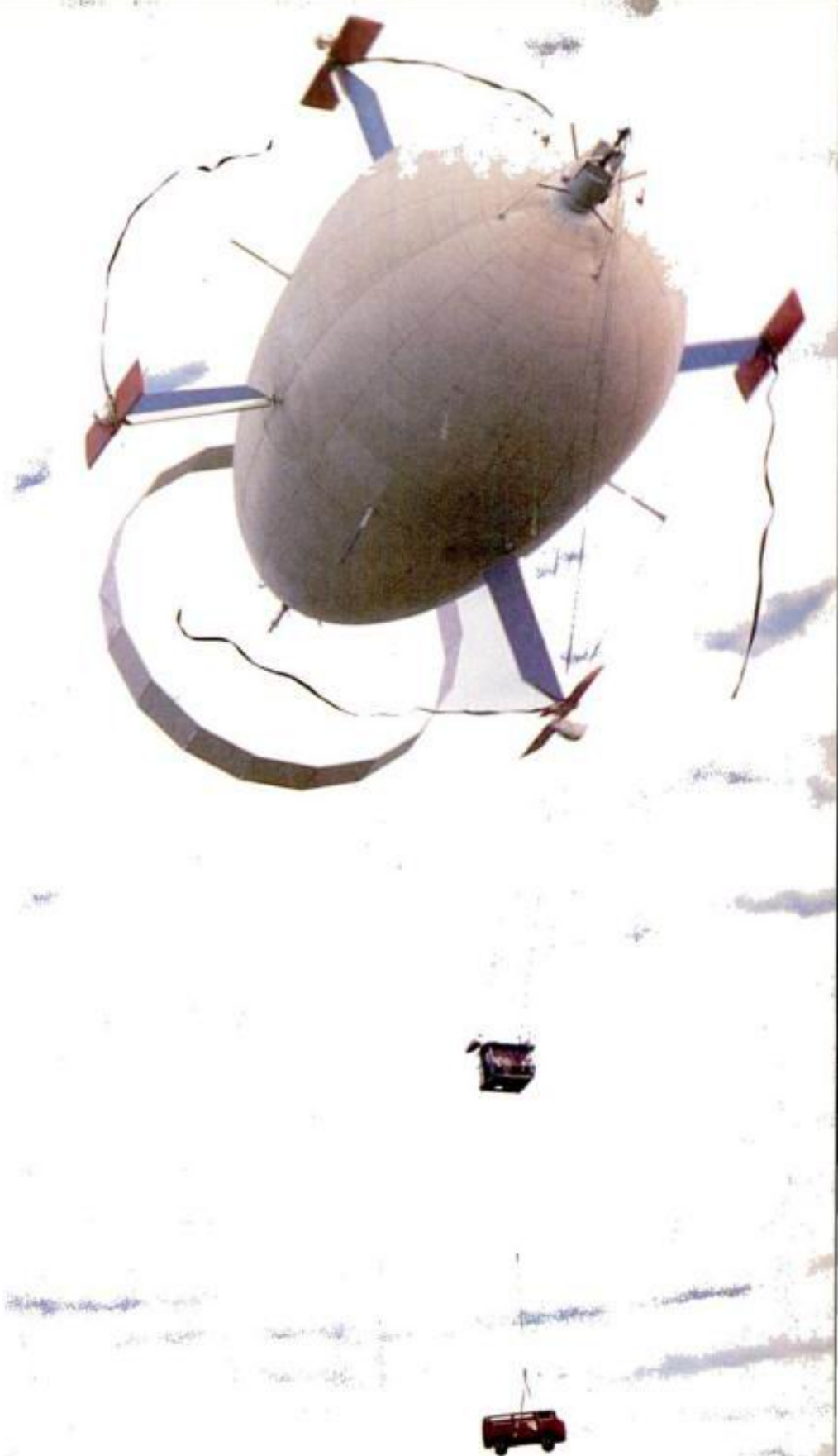
A rebuilt 178-foot-long Cyclo-Crane logged seven hours of flight time under an \$830,000 test contract from the U.S. Forest Service. But the craft didn't meet all expectations. "The rebuilt ship had only two engines," says Haunschild. "The original had four. They were left off the current model to save weight and simplify design problems. But now we haven't got the power to spin at design speed (13 rpm), which would give us more agility. We can only turn at 10 rpm." That drop in performance limited the airflow speed over the wing surfaces to 45 mph (60 mph is what the design specifications call for), which impaired the airship's lifting ability. Cyclo-Crane

managed to haul away a Volkswagen van (see photo)—but not an anticipated two-ton load.

AeroLift's next step: a production model. "We're expecting funding any day now from the British Columbia [Canada] government," Haunschild says. Aerial logging is perhaps the only way to reach 90 percent of the timber in western Canada, where the cost of road building is prohibitive. A 356-foot-long Cyclo-Crane could lift 16

tons and work for hours, it's claimed, replacing heavy-lift helicopters, which carry only enough fuel for short runs.

"There's also plenty of interest in Washington, D.C., from the military," says Haunschild. "They're looking for over-the-beach logistics—lifting and transporting containerized cargo." A full-scale Cyclo-Crane could have a fully fueled range of 3,000 miles, giving the airship the potential for off-shore surveillance.



COMPUTER AND VIDEO MONITORS

ELECTRIFIED BARBED-WIRE FENCE

BLOW-OUT PANELS

CARGO HOLD

ARMED GUARDS

FLOODLIGHTS AND SURVEILLANCE CAMERAS

MOBILE X-RAY BAGGAGE SCANNER

WAITING AREA

METAL DETECTOR

CARRY-ON-BAGGAGE X-RAY SCANNER

CHECK-IN-BAGGAGE X-RAY SCANNER

BULK-BAGGAGE X-RAY SCANNER

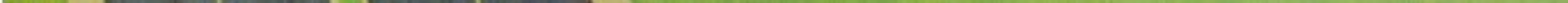
EXPLOSIVES SNIFFER

CONVEYOR BELT

ROBOT BAGGAGE HANDLER

REINFORCED BOMB CONTAINER

VIDEO CAMERAS



terror in the air?

After a string of terrorist skyjackings and bombings brought calls for tightened airport security, a classified federal research program established to develop advanced weapons-detection devices—automated baggage scanners, ultra-sensitive bomb sniffers, and the like—went into high gear. Airport security forces in the U.S. face tremendous obstacles to screening the hundreds of millions of passengers and bags that board aircraft each year. Experts tell what new technology can do to keep terrorists out of our “friendly skies.”

By STEVEN ASHLEY
Painting by Dean Ellis

For a few weeks this summer, it was just about all you heard on the news: the extended hijacking of Trans World Airways Flight 847 from Athens to Beirut, the explosion of a travel bag in a trash can at Frankfurt airport, the same-day detonation of a bomb in checked baggage being unloaded from Canadian Pacific Air Flight 003 in Tokyo, and the suspected sabotage of Air India Flight 182, which crashed into the Atlantic Ocean.

Security procedures at airports around the world were tightened, and then, suddenly, little more was heard of international air terrorism. After all, incidents are relatively rare: 20 skyjackings and three airplane bombings took place last year—not many, considering there were 11 million commercial flights during the same period.

“But what happens if the number of terrorist attacks in the U.S. increases to the level now occurring in the Middle East and Europe?” asks an explosives technician who regularly performs bomb searches for the Secret Service and State Department. “It’s going to come here also; it’s just a matter of time,” predicts a federal anti-terrorist law-enforcement official. If air terrorism does get worse here, what will we do to stop it?

The answer at the moment, say anti-terrorism experts, is meticulous enforcement of present-day security methods at airports, expansion of the federal air-marshall program, and improving intelligence to get early warning of terrorist activities. But in the future a larger role will be played by technology now being developed.

Classified research

In the wake of the recent terrorist epidemic, the Federal Aviation Administration (FAA) has accelerated a classified research effort in laboratories across the country to develop new, sophisticated techniques to detect weapons

and bombs before they get onto planes. Four million dollars was hurriedly diverted from other FAA projects and added to the earlier \$11.3 million airline-security-research budget for 1986. The program is moving on several fronts to find ways to thwart the terrorist threat. Among the important developments:

- A device that will shower baggage with low-energy neutrons. If explosives are present, the nitrogen compounds in them will release gamma rays, which will be detected, setting off an alarm.
- A computerized bomb-recognition system that will analyze the outlines and density patterns of weapons in digital X-ray images of luggage to spot bombs that human eyes might miss.
- A super-sensitive chemical detector, now used to analyze air-pollution samples and to find cancer-causing additions to preserved meats, adapted into an accurate bomb sniffer.
- Chemical and electronic tracers for use as taggants in the electric blasting caps employed in many bombs, making them detectable by special devices.

To find out what has been done on these and other fronts, when the research might bear fruit, and what the chances are of success, I talked to government law-enforcement officials, airline executives, security experts, scientists, and engineers in the field. Most of the time they were unwilling to reveal details about their anti-terrorist work. As one security expert told me, “Once the terrorist knows what kinds of security systems he’s going to face, it’s relatively easy to devise countermeasures. Security depends a lot on secrecy and deception.” Nevertheless, by piecing together references from interviews and collecting data from diverse sources, a general picture emerged of the

Continued

A combination of sophisticated baggage-inspection technology, physical barriers to entry, remote surveillance, and tight security procedures, the super-secure airport would resemble an armed camp. Though many of the security measures depicted would be redundant in one facility, the rendering gives an idea of the obstacles a terrorist would face. Checked luggage would

be inspected for weapons by either ticket-counter X-ray machines or by X-ray scanners and bomb sniffers along the central conveyor belt. Passengers and carry-on baggage would be screened by metal detectors and X-ray machines before entering holding areas. Airport employees, food, cargo, and supplies would be screened before the air-operations area. Lockers, restrooms,

and other potential hiding places would be located behind the security checkpoints. Should a suspect bag get on a plane, the aircraft would be moved to a remote part of the airfield, where a mobile X-ray screening unit would inspect the baggage. If a bomb does explode on an airborne plane, blowout panels would allow the force of the blast to escape.



Super

By STEVEN ASHLEY
Drawings by Ed Lipinski

As the scaffold hoist lurched into action, the voice in my head kept screaming over and over: "What are you doing out here?" I'm dangling a quarter of a mile in the air off the side of one of the World Trade Center towers. I only know that I'm out here for the duration, because there's absolutely nowhere to go on this breathtaking expanse of steel and glass.

Building supervisor Bob DeBellis's invitation to ride down the face of one of New York City's twin towers had come as a complete surprise: I had only asked to see "the rigid exterior frame of many closely spaced columns" that structural engineers say keeps the huge box beams standing in high winds. Now I'm getting a close-up view—too close—of several of those thin steel columns as DeBellis operates the platform, chuckling as we slowly plummet.

Ceaseless buffeting from wind gusts has already abolished any interest in the spectacular vista of New York Harbor behind me, while the incessant creaking of the cables inside the columns has made the steady retreat of the rooftop too unnerving to watch. Down through the scaffold's floor grating, those same columns converge in the distance far below like multiple train tracks in some strange upended railway yard. Actually there's only one

Architect Eli Attia's 130-story proposal for Manhattan's Columbus Circle site has no vertical columns. The structure resolves both horizontal (wind) and vertical (gravity) forces into diagonal load-bearing members that efficiently conduct the forces to the ground. Because there is no net uplift at the base, the structure has a small foundation compared with its 1,535-ft. height.

High-rise buildings have already topped 110 stories, and engineers are designing structural systems that will allow them to go even higher. But whether a new supertall building is attempted depends on economic feasibility, finding a large enough site, and the strong desire for a monument as impressive as the Great Pyramids. How tall can they build them? Engineers say the sky's the limit.

skyscrapers

How high can they build them?

direction in which I'm focusing my attention, and that's straight ahead at the nice safe offices behind the window glass...

I had been brought to this precarious perch by my research into the coming age of superskyscrapers. For today there are signs that even-more-vertiginous buildings than the World Trade Center and its cousins—buildings now on drawing boards across the country—may be built in the foreseeable future. For example, the recent competition for the large Columbus Circle building site in New York City elicited three proposals for buildings taller than 130 stories. "It had people all over the world absolutely drooling," said renowned structural engineer William J. LeMessurier, president of LeMessurier Associates/SCI, in Cambridge, Mass.

Why so high?

Are such superskyscrapers really buildable? What kinds of problems—engineering and otherwise—would they entail? And why would anyone want to build them, anyway?

Ever since the first skyscraper went up just 100 years ago (the 10-story Home Insurance Building, in Chicago), designers have not stopped refining structural framing systems that could give birth to a new generation of superskyscrapers—structures that could eventually bring to fruition Frank Lloyd Wright's 1956 proposal for a mile-high building.

"Nobody is going to build a two-hundred-story skyscraper right off," says Hal Iyengar, eminent structural engineer and partner at the Chicago architectural firm of Skidmore, Owings & Merrill. "We'll march up the scale bit by bit. But I believe that we could build a very tall structure, say, 2,500 to 3,000 feet, fairly easily."

The romance these colossal edifices hold for architects, structural engineers, and real-estate developers is strong and enduring. When LeMessurier speaks of designing supertall skyscrapers, you can hear the excitement behind the words: "If I live long enough, I'm going to build the tallest building in the world. Every red-blooded American boy wants to do that, don't they?" These sentiments are not unusual among his colleagues. Says Iyengar: "Designing tall buildings is very exciting work... it's the structural engineer's dream because the many new problems make the structure a much more prominent element of the overall building design."

And Eli Attia, the well-known architect responsible for the Columbus Circle design proposal depicted here, says, "A really tall building is like no other. After you pass, say, 70 stories, the building becomes a new sort of creature, one that forces you to respond to a different set of challenges from those presented by smaller buildings."

But critics ask, why build so high in the first place? They question the need for these new megastructures, which they see as the result of egoism, nationalistic fervor, or what is variously called the "monument complex," or "Tower of Babel syndrome." They point to the high projected construction costs and negative effects superskyscrapers could have on a city's livability: How do you cope with traffic congestion and darkened streets? How do you deal with all those people and the supplies they need? For instance, James A. Grismer, superintendent of operations at the World Trade Center, told me of the immense logistical problems in supplying the 50,000 workers and 80,000 daily visitors to the vertical city. One statistic: They go through 14,000 rolls of toilet

paper every day, each of which must be delivered to the appropriate floor.

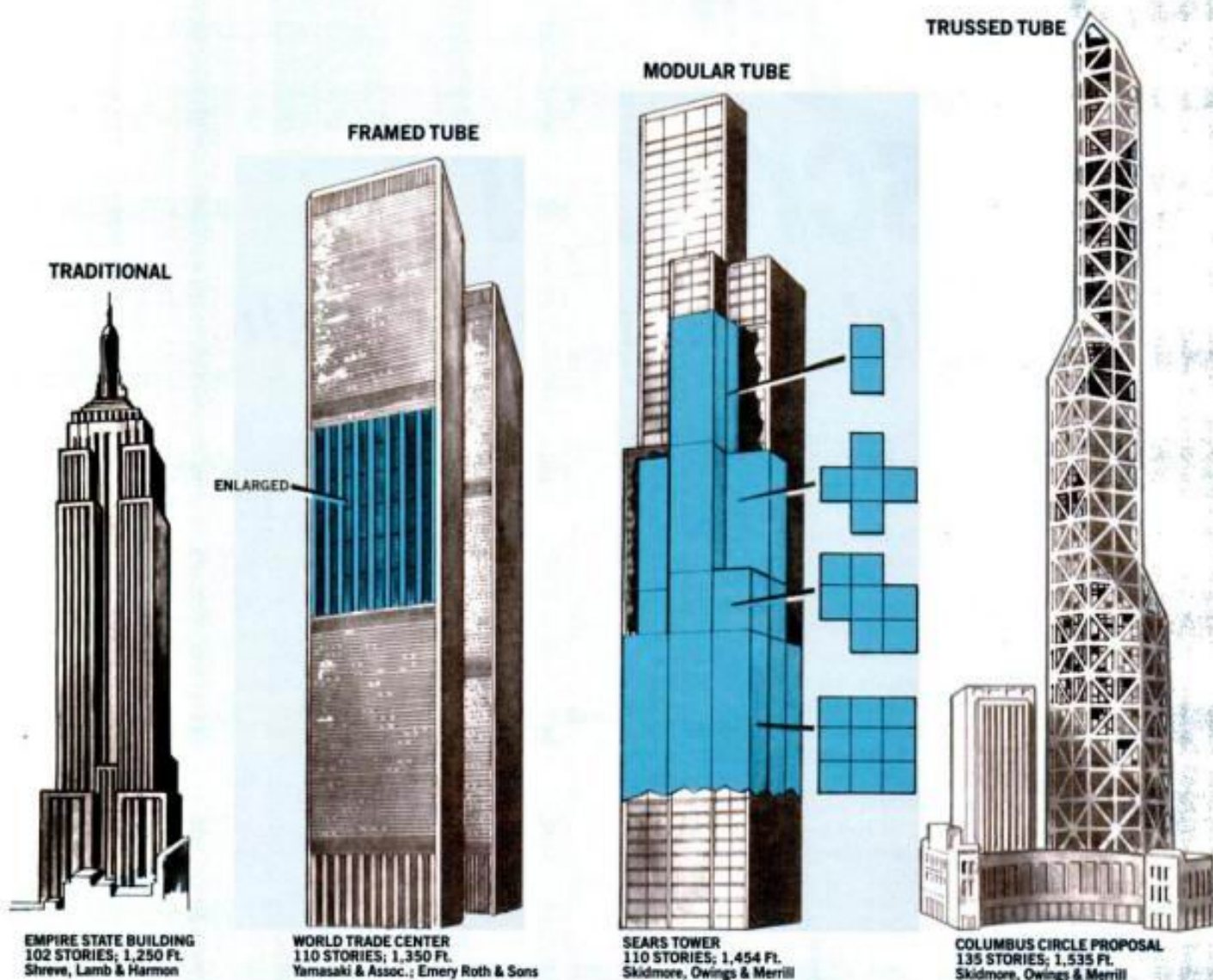
"The real constraints are probably not the engineering or the cost of materials," LeMessurier says. "It's finding a big enough site in a city with zoning laws that make it possible. Most places in the U.S., with the exception of Houston, have laws that say that you can build so many square feet per square foot of land. In New York City, that [floor-area ratio] varies between fifteen and eighteen times the land area, and tall buildings necessarily have a lot of floor area. [The World Trade towers have 9.5 million square feet of rentable space.] But if somebody feels they can finance it and rent it, it will happen."

If architects and engineers do get a crack at a superskyscraper, how will they go about designing it? According to Joseph Colaco, a well-known structural engineer and president of CBM Engineers, in Houston, "The first thing we worry about is the building's aspect ratio—the ratio between a building's height and its base. The rule of thumb is that when the height exceeds approximately six times the minimum base dimension, the building starts to have certain problems.

Round or square?

"Then you have to decide its shape: round, square, rectangular, or whatever," Colaco continues. "Shape is very important to the building's performance in the wind. The drag coefficient of a round building [0.7] is half that of a rectangular one [1.4], so there's twice as much wind load on a rectangular building. Horizontal wind loading is the major force on buildings [even greater than earthquakes]. It's like somebody trying to push the building over."

Continued



The Empire State Building grew out of traditional steel-tier construction methods in which beams and columns are assembled in two directions, says structural engineer Hal Iyengar. He estimates that this type of skyscraper construction has about 25% to 30% of the structural efficiency of a monolithic vertical cantilever (100%; see text). The World Trade Center towers—framed tubes—have extremely close-

spaced, thin columns on the outside, which give the towers a cantilever efficiency of 80%. The Sears Tower, a modular-tube design, has bundles of internal tubes, which open up more space for windows (80% cantilever efficiency). The Columbus Circle proposal of Iyengar's firm is a type of trussed-tube design (90% efficiency). It uses diagonal external members to tie together all the faces in a continuous fash-

Colaco explains that the windward side of the building tends to lift off its foundation, while the leeward side tends to push down. In effect, the result is to convert the horizontal wind forces into vertical forces. Because a building can cope with vertical stresses better than with bending stresses, the engineer seeks to maximize this conversion by placing as much weight as possible at the perimeter of the building, and away from the center. "That gives you the biggest leverage," Colaco says. "And that's what's given rise to the so-called tubular design of skyscrapers."

In essence, the tubular design acts as a hollow, vertical cantilever—like a pipe stuck in the ground. It withstands both vertical (gravitational) and horizontal (wind and earthquake) loads.

"Imagine a building like a grain silo—a tall circular concrete wall on the outside with just a few openings," says Colaco. "This building is monolithic, or a one-hundred-percent cantilever. In terms of structural efficiency, this is optimum. But because a skyscraper is a machine for living—and not a tomb—the architect says, 'I've got to have windows.' This is

where the engineer and the architect must use creativity to get the building as close to one-hundred-percent structural efficiency—a monolithic cantilever—and still provide functional features like windows."

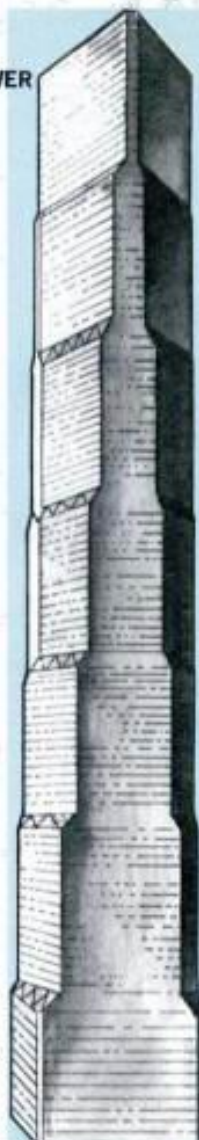
Obviously, a building's materials must be strong enough to resist gravitational and horizontal forces. But as buildings grow taller, the dominant problem tends to be not strength but stiffness. "Physically, there is nothing you can do to prevent building sway," Colaco points out, "but since a building has people in it, you have to keep it within limits. A building cannot be

INTERNALLY BRACED
TUBE



BANK OF THE SOUTHWEST TOWER
82 STORIES; 1,220 Ft.
Murphy-Jahn Assoc.

GUYED TOWER



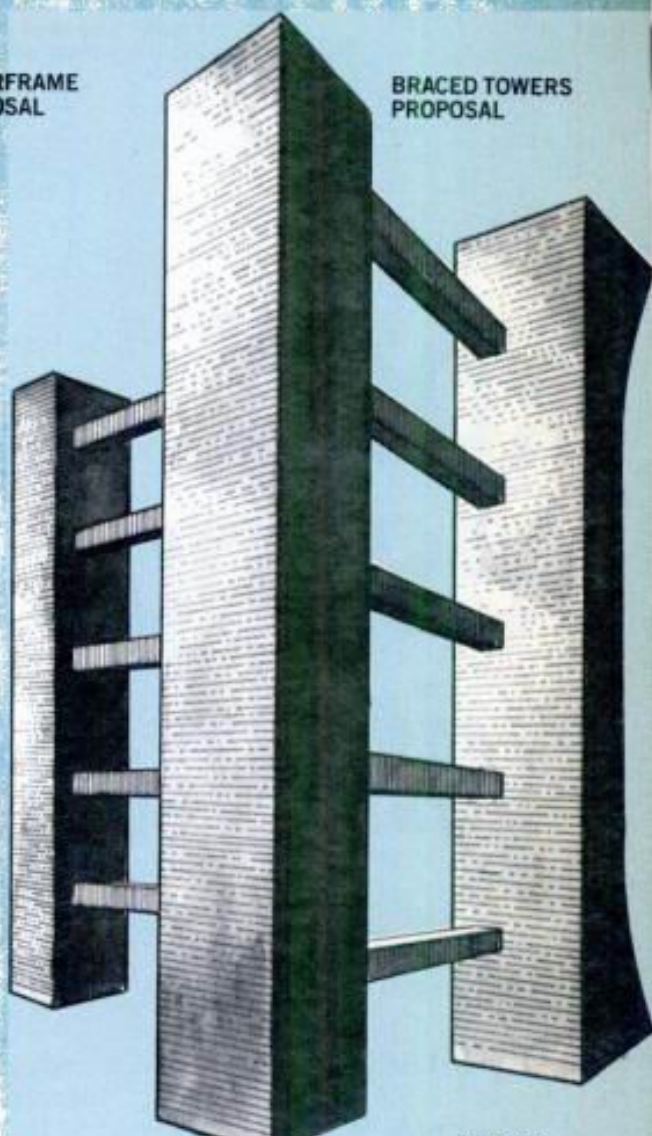
CHICAGO WORLD TRADE CENTER PROPOSAL
210 STORIES; approx. 3,000 Ft.
Harry Weese & Assoc.

SUPERFRAME
PROPOSAL



140 STORIES; 1,800 Ft.
DeSimone & Chaplin

BRACED TOWERS
PROPOSAL



200 STORIES; approx. 2,400 Ft.
DeSimone & Chaplin

BUILDINGS
NOT TO SCALE

ion, like winding a cord around the structure in two directions. The Bank of the Southwest Tower is an internally braced tube that relies on triangular steel frames that connect to columns on opposite faces (efficiency not given). The proposed Chicago World Trade Center is a gayed-tower design that takes a 45° turn as the building rises. This design emulates, to some degree, the action of guy wires fixed to

the ground (efficiency undetermined). Superframe designs concentrate most of the load-bearing material into massive corner elements tied together with huge horizontal beams (85% efficiency). Braced towers are just that—several buildings tied together with sky bridges for stability (efficiency undetermined). These towers require an especially large construction site, which can be a rare find in a big city.

so limber that desks are rolling back and forth, doors are banging, and so forth."

As a rule of thumb, a 1,500-foot building in a maximum hurricane wind (one that occurs once every 50 years) should not sway at the top more than three feet. "Otherwise, you'll have problems with glass popping out and partitions cracking," says Colaco. "Normally, the sway is unnoticeable—maybe an inch or two.

"But that's not all. People up there are motion-sensitive, so you have to restrict the perception of motion—the acceleration of the building. Wind

forces are not very smooth, and when they hit a building, they cause a kind of jerkiness, like when you slam on the brakes of a car. So we have to limit how much the building can accelerate at the top. We estimate it first mathematically, then we simulate the dynamics of the whole building in a wind tunnel."

Deadly shakes

One less obvious problem that buildings encounter to a greater and greater degree as they rise higher and higher is called vortex shedding. Indeed, the phenomenon was not well understood

until the construction of the World Trade Center in the late 1960s. A pioneer in this field, Alan Davenport, director of the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario, London, Ontario, says: "Vortex shedding occurs when you put something rather blunt into an airflow. The air tends to veer one way and then the other, causing the wake to wander from side to side in eddies. This changes the pressure on the side faces in a periodic manner, depending on the speed of the flow. If these fluctuating impulses act at an

[Continued on page 96]



21st-century superfighters

Dramatic leaps in aerospace technology have occurred since the F-15—the Air Force's hottest fighter—was designed in 1969. The new generation of fighters will be faster, more agile, and harder to detect than today's warbirds. Lightweight composites, smart avionics, wings that change shape, and powerful engines will make them swift and deadly performers.

By **STUART F. BROWN**

Cutaway painting by Barry Bichler

Cruising at supersonic speed into the night, the veteran fighter pilot is on routine patrol. Stars twinkle in the indigo sky. The heavens seem peaceful. Suddenly, the radar display on the fighter's instrument panel shows three, then seven yellow question marks approaching from the east 150 miles out. "Bad guys or good guys?" the pilot wonders, glancing at the cockpit display to confirm that his detection sensors are working properly.

Then, one by one, the radar blips turn an ominous red. The fighter's friend-or-foe identification circuitry has done its job. "Bogies," the machine informs the pilot in a humorless synthetic voice that sounds like it works for the telephone company. "Three of us against seven of them, with orders to engage," the pilot tells himself. "I need a plan of attack... quick."

"Virtual world," he barks into the microphone in his oxygen mask. The

inside of his visor fills with a daylit color image of the night skies ahead. The seven approaching targets appear with inverted cones that depict the range of their airborne radars projecting from their noses. "They're still a few minutes away," he thinks, focusing for a moment on the time-to-intercept numbers ticking away at the edge of his vision.

Three of the oncoming targets are flying ahead of the remaining four. The pilot fixes his gaze on the nearest one. "Range?" he queries. A blinking window next to the lead aircraft shows 118 miles. "Altitude?" The display reads 37,000 feet. "Time to AMRAAM range?" he asks. Two minutes, 10 seconds, the display indicates. Then he can fire one of his medium-range air-to-air missiles. "Advisory, AMRAAM, enter," the pilot orders. The aircraft will remind him when missile-launch time has arrived.

"God's eye," the pilot commands. Immediately, like a celestial being, he is looking down from above on his area of the sky. From the God's eye view he

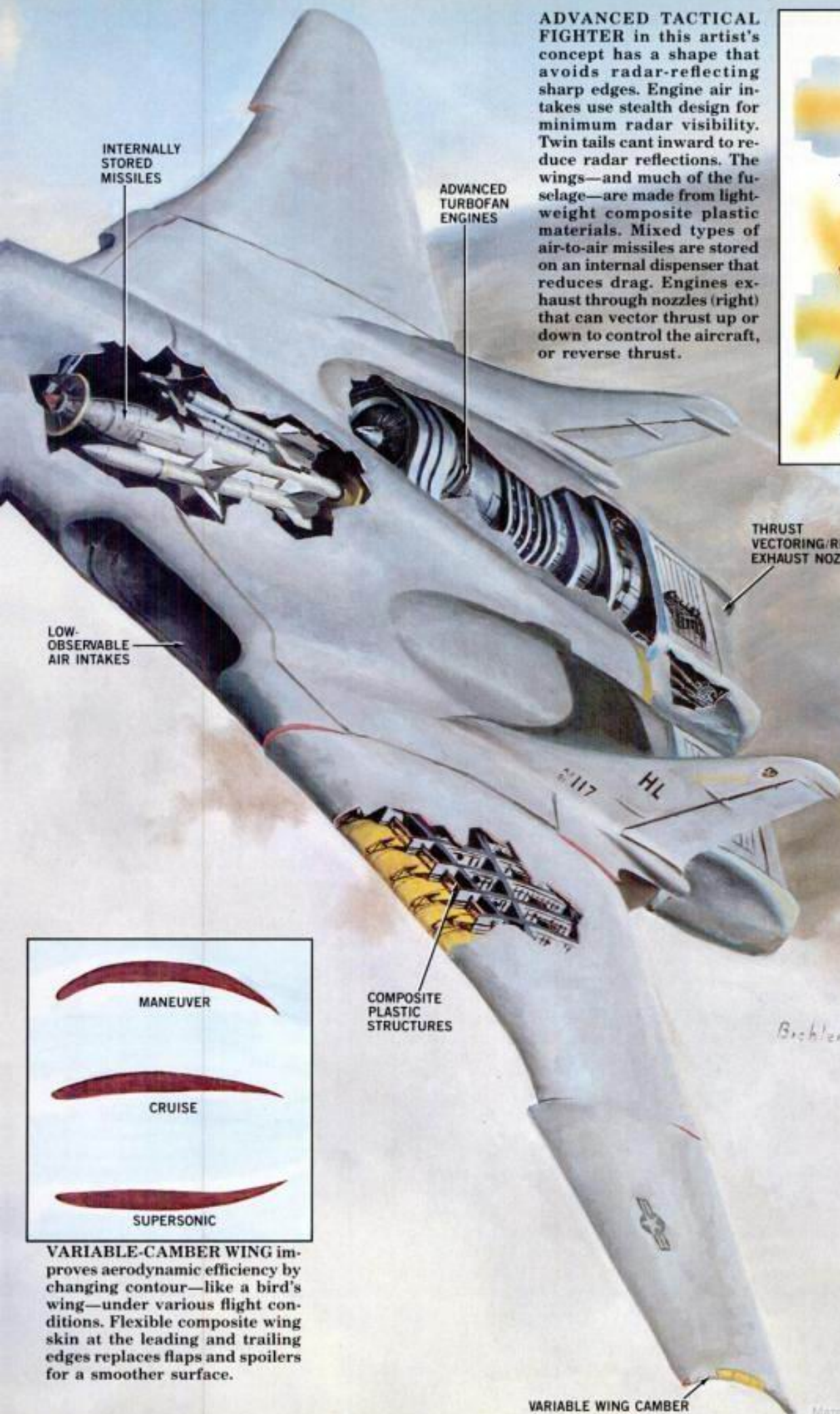
sees his own aircraft in the middle of the scene. To the left are his two wingmen, marked in blue. Ahead are the seven red intruders, the symbolic cones of their search radars moving steadily nearer. The pilot locks his eyes on the image of the lead enemy fighter. "Target, AMRAAM," he orders, marking the enemy for his first missile shot. Transmitting over a radio link, he designates the next pair of targets for standoff shots by his wingmen. Their acknowledgments appear on the display.

Dominate the skies

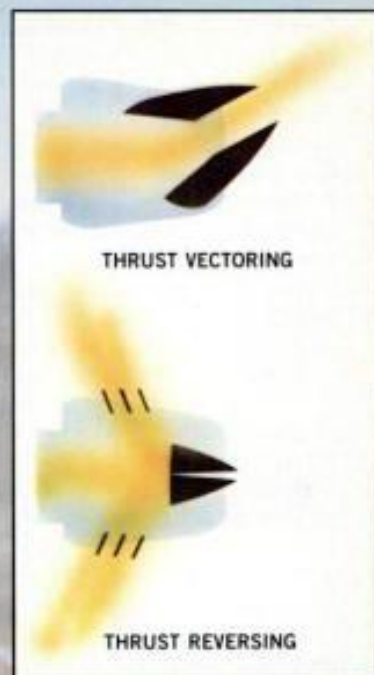
This is what the scene might look like from the pilot's point of view just before a dogfight, around the year 2000. With such scenarios in mind, the U.S. Air Force is planning fast, agile, highly computerized aircraft that will pit the keen edge of American technology against the vastly greater number of aircraft Soviet forces are expected to field.

Right now, a smorgasbord of fighter

Continued



ADVANCED TACTICAL FIGHTER in this artist's concept has a shape that avoids radar-reflecting sharp edges. Engine air intakes use stealth design for minimum radar visibility. Twin tails cant inward to reduce radar reflections. The wings—and much of the fuselage—are made from lightweight composite plastic materials. Mixed types of air-to-air missiles are stored on an internal dispenser that reduces drag. Engines exhaust through nozzles (right) that can vector thrust up or down to control the aircraft, or reverse thrust.



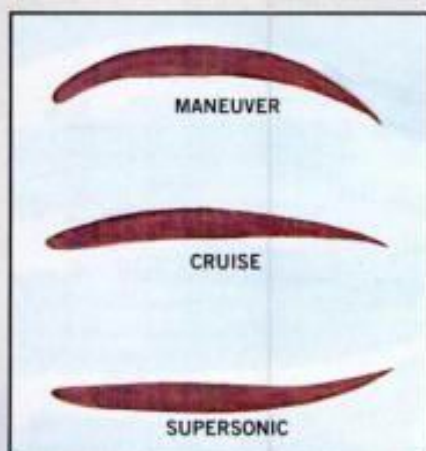
INTERNALLY
STORED
MISSILES

ADVANCED
TURBOFAN
ENGINES

THRUST
VECTORING/REVERSING
EXHAUST NOZZLES

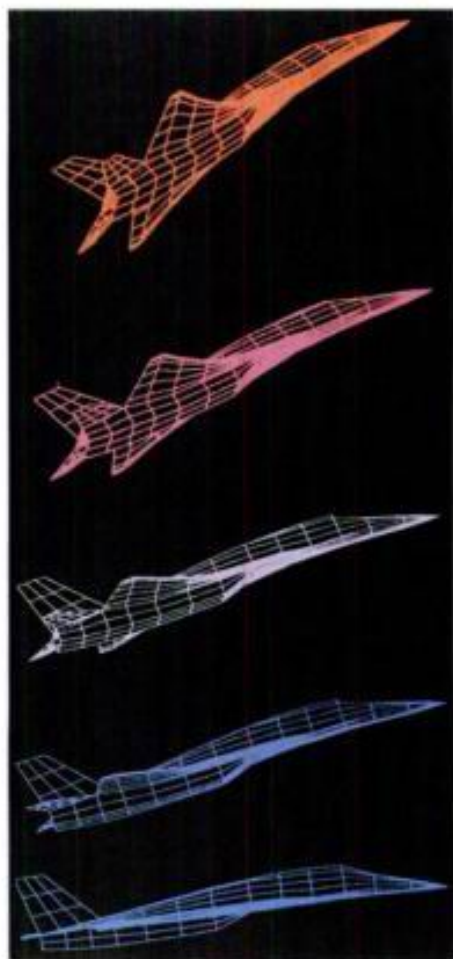
LOW-
OBSERVABLE
AIR INTAKES

COMPOSITE
PLASTIC
STRUCTURES



VARIABLE-CAMBER WING improves aerodynamic efficiency by changing contour—like a bird's wing—under various flight conditions. Flexible composite wing skin at the leading and trailing edges replaces flaps and spoilers for a smoother surface.

VARIABLE WING CAMBER



These computer drawings were produced by the PAN AIR aerodynamic computation system. The method is used by Boeing to refine aircraft designs before wind-tunnel tests.



A single set of aircraft performance specifications can result in a surprising diversity of design approaches. The ATF concept at top by McDonnell Douglas Corp. depicts a delta-wing fighter capable of cruising at supersonic speeds. Grumman Aerospace Corp. drafted the fighter above, which uses fuselage-mounted canards and thrust-vectoring exhaust nozzles. The Lockheed-California Co. design at left features carefully sculpted surfaces to minimize radar reflections. Other companies competing to build the ATF are General Dynamics, Northrop Corp., and Rockwell International.



Features under study for advanced fighters include forward-swept wings.

Digital flight control makes this maneuverable but unstable design flyable.

weight aluminum-lithium alloys and ceramic whisker-reinforced metals, they will make the aircraft 20,000 pounds lighter than fighters built entirely from conventional metal alloys.

Second, variable-camber wings will automatically change their curvature in flight to maximize lift and minimize drag for fuel-efficient cruising. Flexing the wings eliminates the need for conventional flaps and ailerons.

Stealth vs. agility

Improvements in Soviet fighters and air-defense radar systems have made it much more difficult to survive the modern-day aerial battle. The advanced technology bomber currently being developed by Northrop Corp. (better known as the stealth bomber), and Lockheed's so-called "F-19" stealth fighter, place primary emphasis on making the aircraft virtually invisible to radar and other sensors. This is done partly by using special mate-

rials and coatings that absorb radar signals instead of reflecting them, and partly by equipping the aircraft with sophisticated electronic black boxes that obscure its radar signature.

The primary stealth technique involves paying careful attention to the airplane's shape. Here, it's important to avoid creating sharp edges and large, flat surfaces. Openings such as engine intakes and exhaust nozzles must also be carefully sculpted to minimize their radar reflectivity. The flying characteristics of the pure stealth aircraft, however, will be somewhat compromised by their chief goal of remaining unseen.

With the ATF, the Air Force is demanding a lot: It wants the new fighter to be stealthy *and* a great aerobatic performer at the same time. "Our goal is to have as little impact as possible on performance, size, and cost, and still make the airplane nearly invisible. Minimum profile from any

angle is what you're looking for," observes Piccirillo. "We also want the ATF to fly twice as many hours as the F-15 between groundings for unscheduled maintenance," he adds.

Developing passive sensing devices for fighters is another top priority. Because they merely gather signals from external sources instead of emitting any of their own, passive sensors operate without giving away the game to enemy pilots. The development of miniature high-resolution infrared imaging devices should give pilots the ability to see well-defined TV images of aircraft more than 10 miles distant—at night.

Called focal-plane arrays, these sensors see the heat energy radiated by an aircraft's engines and structures and use it to generate an image. One version, developed by the Electro-Mechanical Division of Northrop Corp., has 16,384 sensors packed onto a 1/2-inch-square semiconductor chip. The sensor array's compactness makes it suitable for air-superiority fighters where size and weight are critical considerations.

Radar is also changing. Flat-plate phased-array antenna designs use as many as 1,600 small microwave emitter-receiver units that scan the sky electronically, gathering data more rapidly than conventional parabolic-dish antennas, which must rotate quickly within the aircraft's nose. A phased array can have malfunctions in as many as 15 percent of its small emitter-receiver modules without suffering a major decrease in its performance.

Phased-array antennas also offer the advantage of being less visible to enemy radar than are the parabolic dish types. Further, it may be possible to save weight and space by performing multiple functions—such as radar, electronic countermeasures, missile warning, and friend-or-foe identification—through time-sharing on a single broad-band phased-array antenna.

The design trade-offs

Aircraft designers are scrambling to meet the Air Force's demand for a fighter that's both agile and stealthy. Sitting in a fenced-off warehouse in the shadow of a prototype graphite-thermoplastic composite fighter wing (see photo), Richard Hardy, ATF program manager at Boeing Military Airplane Co. in Seattle, describes to me how his company uses computers to handle the design tug-of-war.

"Stealth versus agility is the key design trade for ATF. It's not a simple problem. We simulated hundreds of

[Continued on page 112]

BIOSPHERE

When the air lock is sealed in June 1989, eight experimenters who call themselves Biospherians will begin a two-year survival test in a totally enclosed mini-Earth. This experiment could be a model for future space colonies.

By NAOMI J. FREUNDLICH

It was warm and humid in the tropical rain forest as the Biospherian reached up to pick some ripe bananas off the broad-leaved trees. About 100 feet away, he could see one of the other terrarium inhabitants strolling around the mini-ocean, making sure the mechanically generated waves were properly feeding the coral reef. A little farther south, the botanist of the team was studying the progress of some reeds in the tidal marshes. The Biospherian walked over to the edge of his man-made world and looked out, pressing his face against the cool glass. Another broiling hot, dry day out on the desert, he thought. Sealed in their man-made mini-Earth he and his fellow colonists were immune to the outside environment, like tropical fish swimming around in a giant aquarium.

Next month, ground will be broken in the Arizona desert for this 2.5-acre totally enclosed complex called Biosphere II—Biosphere I being Earth. In June 1989, the air lock will be sealed and eight people will attempt to live in Biosphere II for two years. Apart from computer communication, the Biospherians will be completely shut off from the outside world, receiving neither food, oxygen, water, nor any other supplies during their stay. Energy may be supplied from outside until solar technology becomes cost effective. They will have small farming facilities to grow food, plant- and tree-filled areas to provide oxygen, and rain-making and wind machines to keep air and water cycling through.

The effort is being funded by a private company called Space Biospheres Ventures (SBV). But important contributions are being made by experts and scientists from several renowned organizations, including the Smithsonian Institution, the New York Botanical Garden, the University of

Arizona's Environmental Research Laboratory (ERL), and the U.S. Geological Survey. These workers are not simply designing an extravagant way of avoiding the summer desert heat; their ambitious goal is nothing less than to design a Biosphere that will function as a permanent manned space colony on Mars.

Such grand schemes for self-sustaining colonies in space used to be the realm of science-fiction writers and other visionaries. Now the concept is seen not only as practical, but as an eventual necessity. The 1986 annual report of the National Commission on Space said that developing man-made biospheres is vital if we want "to explore and settle the inner solar system." James Brecht, director of NASA's Life Sciences Division, says the project "is a very interesting experiment... I believe they're going to learn an awful lot that people don't know now about complex biological communities."

To learn just what such a community would be like and how all of its intricate parts would work together, I went to Arizona and the planned site of Biosphere II.

Revolutionary experiment

Biosphere II, I found, is an attempt to recreate the complex series of cycles that have sustained life on Earth for millions of years. For example, animals breathe in oxygen and release carbon dioxide as a waste product. Plants—from huge tropical forests to microscopic algae in the sea—do the reverse. Water evaporates from the ocean, falls on land as rain, is used by plants and animals, and returns through streams and rivers to the sea. After they die, animals and plants are decomposed by bacteria and other organisms, returning carbon dioxide to the atmosphere and countless other elements to the soil.

Biosphere II, like Earth, will be



Designers of Biosphere II are linking several different biomes, or ecological systems, to form a single closed system. The four-story white, domed building (1) is the living and working quarters for the eight Biospherians, and the tiered platforms (2) will be their intensive farming areas. Food, fiber crops, and domestic animals will be located here. The tallest (80 ft.) natural biome is the tropical rain forest (3). A ceiling-mounted cooling coil condenses moisture in the air into rain. A stream flows down a mountain waterfall, out of the rain forest, and through a tropical savanna and a freshwater marsh. After passing through a saltwater marsh, the stream empties into the shallow ocean (4), which contains a living coral reef maintained by mechanical wave action. At its southern end (5), the ocean is shaded by tidal-marsh platforms to simulate deep ocean. Water evaporation from the ocean is driven by air currents back to the rain forest. The desert (6)—the final biome—follows a transition thorn-scrub forest.

made up of a number of different biomes, or small ecological systems. Selected for the experiment were such diverse biomes as a tropical rain forest, desert, ocean, savanna, and marshes, each designed to contribute (at a much faster rate than on Earth) to the overall balance and cycles necessary to sustain life.

Biosphere will be built in Oracle, a



tiny town located in the foothills of the dry and barren Santa Catalina mountains, less than an hour's drive north of Tucson's city limits. As I turned up a dirt road marked by a sign for SunSpace Ranch Conference Center, I was struck by the similarity of this landscape to an extraterrestrial one; the dusty, rocky, dry mountains ahead could have been on Mars.

Here in the middle of the desert, the SBV architects and their scientist collaborators are seeking an elusive goal. In all the years that NASA scientists and other researchers have been working in the field of completely closed ecological systems, there has been only one success—a sealed sphere containing shrimp and algae that has survived for 17 years. Developed for

NASA by Joseph Hanson of the Jet Propulsion Laboratory, the system is now being sold commercially as the EcoSphere. But nothing remotely on the scale of Biosphere II has ever been attempted.

During my visit, there was a hum of activity at the SunSpace Ranch. Some workers were tending huge

Continued



In Biosphere II there will be limited space for food production. The plan is to have the greatest variety of plants and animals in the smallest possible area. A key element is fish farming (above). The water flushing out of the large vats of orange and gray fish—tilapia—eventually is used in the irrigation system for the plants. On its way, microorganisms embedded in filtering water wheels break down ammonia from the fish waste water into nitrates and nitrites. The water is then mixed with other nutrients and used to irrigate and feed hydroponically grown vegetables (left). The plants readily remove all nitrogen compounds from the water. The water evaporating from the plants or running out of the bottom of the farming platforms will be collected, percolated through soil-bed reactors, and reused.

greenhouses filled with hydroponically grown vegetables (grown hydroponically to save space). When Kathy Dyhr, administrative director of the Biosphere project, guided me through one of the greenhouses, ladybugs were everywhere, including all over me. Because Biosphere II is completely enclosed, no agricultural chemicals can be used. Instead, ladybugs and microscopic ground wasps will be the de-

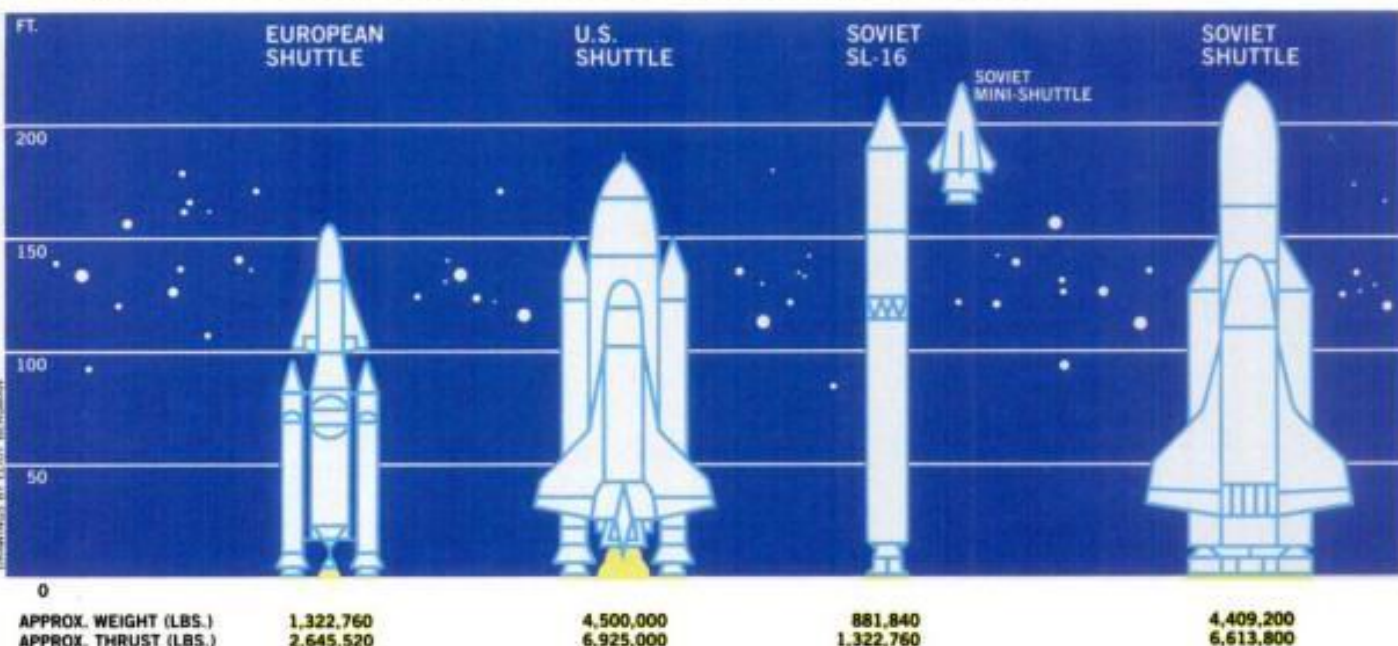
fense against aphids and other pests.

Near the greenhouse, horticulturist Stephen Storm runs a tissue-culture laboratory that serves as a kind of storehouse for crops. One just like it will be housed in Biosphere II. If a crop fails to survive inside the man-made world, a slightly different species, stored as seedlings in the tissue-culture lab, could take its place quickly.

Selection of plants that will be used in Biosphere II is, of course, critically important to the success of the project. I talked with Ghilleen Prance, senior vice president for research at the New York Botanical Garden, who is in charge of picking the flora for Biosphere II's tropical rain forest. He explained that in addition to making sure oxygen and other cycles were bal-

(Continued on page 94)

Sizing up the competition: orbiters and launch vehicles



Hermes, a small vehicle, sits atop the Ariane 5 rocket that launches it. The American and Soviet shuttles ride piggy-

back on large external fuel tanks. The Soviet mini-shuttle, or reusable spaceplane, is launched by the SL-16 booster.

during recovery operations in the Indian Ocean by Australian military pilots in 1984.

Called a reusable spaceplane by the Pentagon, which maintains that it is under continuing development and may be intended for anti-satellite operations, the little space flyer could carry two cramped cosmonauts on a brief mission. Other experts contend that, because it has not been space-tested since December 1984, the craft was part of development tests for the larger shuttle or for other advanced spacecraft. The mystery continues.

At the same time, there is no mystery about a small shuttle being developed in France, with the backing of the 11-nation European Space Agency. Dubbed Hermes, the orbiter will be launched by an expendable Ariane 5 rocket, which is also in development. Hermes will carry four or more European astronauts and a 10,000-pound payload into orbit, then return for a runway landing on Earth. Its first flight is planned for 1995 or '96.

And in the Far East, two Japanese agencies—the National Aerospace Laboratory and the Institute for Space and Astronautical Science—are pursuing their own winged space vehicles. Japan's shuttle work remains preliminary; the government has not formally approved a full-scale program. The country's space agencies have asked for approval beginning in 1987, and hope to launch a small manned shuttle atop a disposable rocket before the year 2000.

It's the Russians who are closest to an operational system. "We've been watching the Soviet heavy-lift booster and shuttle programs for years," said Marcia Smith, the leading specialist in aerospace systems at the Library of Congress and president of the American Astronautical Society. Smith monitors the Russian space program and regularly advises Congressional committees on its activities and plans. "The two programs are tied together, and they're getting ready to fly at last," she told me.

Activity in the Russian program accelerated sharply in the past two years. Photographs of the Soviet launch facility at Baikonur Cosmodrome near Tyuratam taken last summer by the French SPOT earth resources satellite [PS, Feb.] show that construction of a huge vertical assembly building, similar to the National Aeronautics and Space

Administration's facility at Kennedy Space Center, in Florida, has been completed. The photos also show huge launch pads of the type needed for heavy-lift boosters, a road-and-rail system for moving large vehicles, and a 15,000-foot runway to be used by shuttle orbiters returning from space.

Nicholas Johnson, advisory scientist at Teledyne Brown Engineering in Colorado Springs, Colo., and author of the respected annual report *The Soviet Year in Space*, questions whether spy satellite photos showing the orbiter-Bison combination mean that approach and landing tests have begun at Baikonur. "We don't know if the Bison is physically capable of carrying a reasonably loaded shuttle to altitude. Carrying an orbiter shell and a full-up vehicle to drop altitudes are two very different things." Other experts are convinced that drop tests indeed began in early 1986.

At least one near-accident occurred during transport tests. While landing at Baikonur with the orbiter still attached, a Bison bomber skidded off the runway. Satellite photos taken in the spring of 1986 luckily caught the incident almost as it happened, according to the Pentagon, but didn't reveal whether aircraft or spacecraft was damaged. The Russians aren't saying.

Considering the risks involved, at least one expert thinks the first Soviet shuttle flight will be unmanned. "They have auto-land capability and don't need a crew," Smith told me. "So do we, but our astronauts won't use it. They want to be in control. But I expect maybe two unmanned tests before [the Soviets] fly cosmonauts. They are incredibly conservative in their program. It's probably because of the level of confidence they have in their technology. We just have more confidence in ours."

Because of winter weather constraints, the Russians typically fly first missions of new hardware in late February or March. If that pattern holds, the countdown for an un-

THE OTHER



SOVIET

Delta-winged like its U.S. cousin, the orbiter will ride atop an external fuel tank with strap-on boosters (left). A mini-shuttle (above, approaching a Soviet space station) could carry two cosmonauts on short missions.

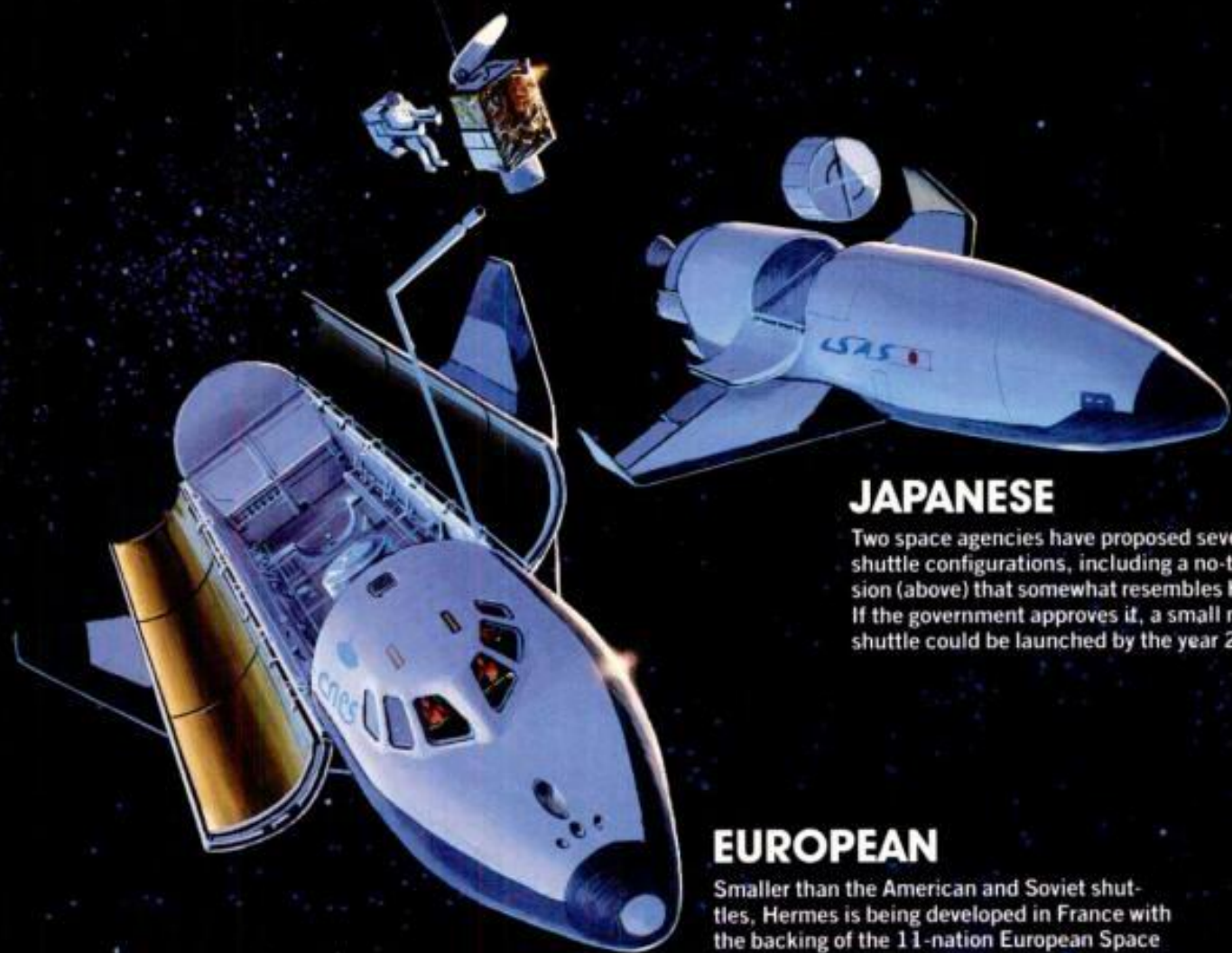
With the U.S. shuttle program temporarily grounded, competition from foreign spacecraft is heating up. Soviet, European, and Japanese manned shuttles may be plying the space lanes before the century ends.

By **JIM SCHEFTER**

Paintings by Attila Hejja

The Bison bomber circled slowly over the Siberian steppes, struggling for altitude under the heavy load of a second aircraft-like vehicle strapped and bolted to its back. Hundreds of miles above the bomber, a United States spy satellite on routine patrol peered down through

SHUTTLES



JAPANESE

Two space agencies have proposed several shuttle configurations, including a no-tail version (above) that somewhat resembles Hermes. If the government approves it, a small manned shuttle could be launched by the year 2000.

EUROPEAN

Smaller than the American and Soviet shuttles, Hermes is being developed in France with the backing of the 11-nation European Space Agency. Slated to fly in 1995 or '96, it will service satellites and dock at space stations.

its powerful telescopic lens and recorded a series of images that quickly found their way to intelligence analysts in Washington, D.C., early last year.

The images were the Pentagon's first hard evidence that the Soviet space-shuttle program had moved into a new phase. Transport tests, perhaps even approach and landing flights, were underway.

Long the subject of rumors circulating in the international aerospace community, the Soviet shuttle—variously code-named Albatross, Kosmolyot (*kosmos* means "space"), and Furan (snow)—is about to come in from the cold. U.S. Department of Defense experts predict that a manned Soviet shuttle will make its maiden voyage in 1988, perhaps even before the U.S. resumes shuttle launches, now scheduled for February 1988. Meanwhile, unmanned tests may increase the Soviet lead in the space race.

Russia's launches will mark the beginning of a new in-

ternational competition in orbit. The facts are clear. Competition for the rights to resupply space stations, service satellites, and ferry passengers to and from orbit with reusable winged spacecraft is booming. Before the year 2000, vertical-takeoff orbiters built by the Soviets, the Europeans, and the Japanese could be flying along trajectories that the U.S. shuttle once traveled in solitude. To find out more about the aggressive space-shuttle programs sprouting overseas, I spoke with a variety of U.S. experts on the Russian space program, and with the head of the European program. Here's what I learned.

Two spacecraft could carry the Soviet red star insignia. The second, and much smaller, Soviet shuttle vehicle has already been test-flown in subscale version at least four times. The tiny craft, shuttle-like in appearance but with up-tilted wing tips, was photographed in excellent detail

Continued

"The package of technological advances that we could incorporate into a new airplane around 1992 is the greatest since we brought out the 707 in 1958," says one Boeing executive. And the list of possible improvements that could be incorporated in tomorrow's airliner is extensive.

First and foremost are advanced prop-fan engines that move a far larger volume of air per unit of aviation fuel than today's conventional turbofans. General Electric's ultra-high-bypass engine (lower right) has no gearbox, which many engine designers consider a maintenance problem.

The wings themselves will have many refinements that will improve their aerodynamic efficiency. High-aspect-ratio

wings—large spans, slender planforms—provide high cruising efficiency. Specially shaped supercritical airfoils—flattened on top, bulging on the bottom—decrease drag and provide greater room for fuel. Winglets, vertical wing-tip blades, smooth out drag-producing vortices that normally follow the tips. Laminar flow control (lower center), which may be used in some form, has special holes or slots in the wing's surface, which suck in drag-causing eddies that form at the boundary layer. Computerized stability augmentation involves using a smaller tail, thus trading some static aerodynamic stability for decreased drag. The computers monitor the airplane's stability and automatically (without

The next generation airliner—three dozen ways it'll be better

ADVANCED AVIONICS
(GLOBAL POSITIONING SYSTEM,
MICROWAVE LANDING SYSTEM,
TRAFFIC COLLISION AVOIDANCE SYSTEM,
DOPPLER RADAR SYSTEM)

DIGITAL FLIGHT
CONTROL SYSTEM
(ACTIVE STABILITY
AUGMENTATION)

PLUG-IN
LAVATORY
MODULE

MOVABLE
GALLEY
MODULE

MOVABLE
COMPARTMENT
DIVIDERS

EXIT LIGHTS LINING AISLES

ACOUSTICALLY DAMPED
AND ISOLATED CABIN

PRECISION
SKIN PANEL
MATING FOR
SMOOTH AIRFLOW

FLAT-PANEL
INSTRUMENT
DISPLAYS

MINI-STICK
CONTROLLER

NASA/AMES ADVANCED-
CONCEPTS FLIGHT SIMULATOR

WIDER SEATS WITH
QUICK-CHANGE
PITCH ADJUSTMENT

FLAT-SCREEN SEAT-BACK
ENTERTAINMENT SYSTEM

DRAG-REDUCING RIBBLETS
(SURFACE GROOVES
PARALLEL TO AIRFLOW)

FIRE-RESISTANT
CABIN
FURNISHINGS

LARGER OVERHEAD
STORAGE BINS WITH
BUILT-IN HANDRAILS

FIBER-OPTIC
NETWORK

LAMINAR
FLOW/TURBULENT
BOUNDARY CONTROL
SYSTEMS

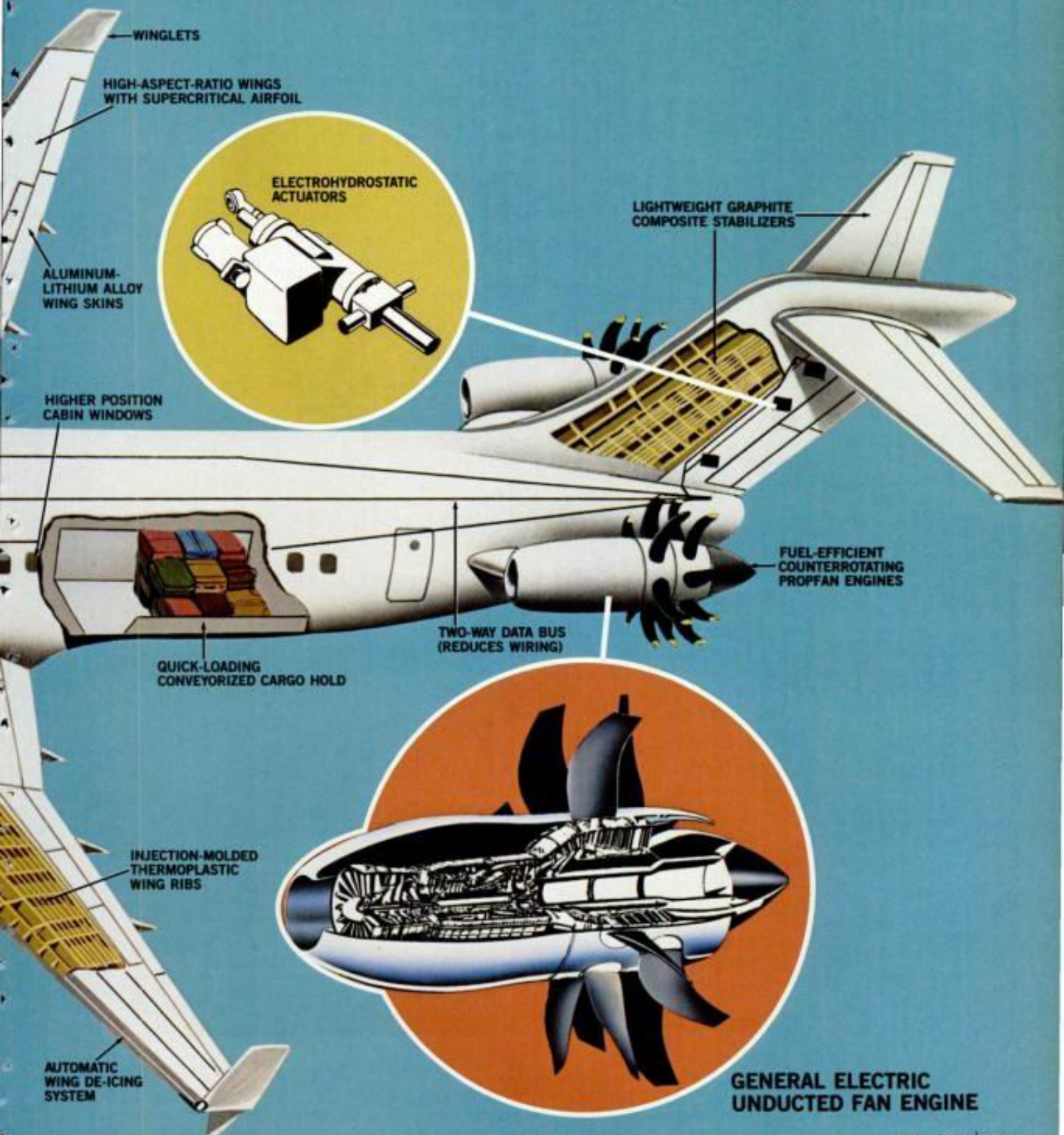
the pilot's input) compensate with small control surface movements. Riblets, thin grooves in the skin, also cut drag.

Besides being more roomy, the flight deck will incorporate several systems that will make flying safer and easier. These may include expert pilot-assistance computer systems and voice-actuated displays. The global positioning system will use signals from navigation satellites to pinpoint the airliner's position on the map. On approach to the runway, the airplane will ride down a microwave beam sent out by the airport. The traffic-avoidance system will alert the pilot (independently of the ground-based traffic-control system) when another plane comes into dangerously close proxim-

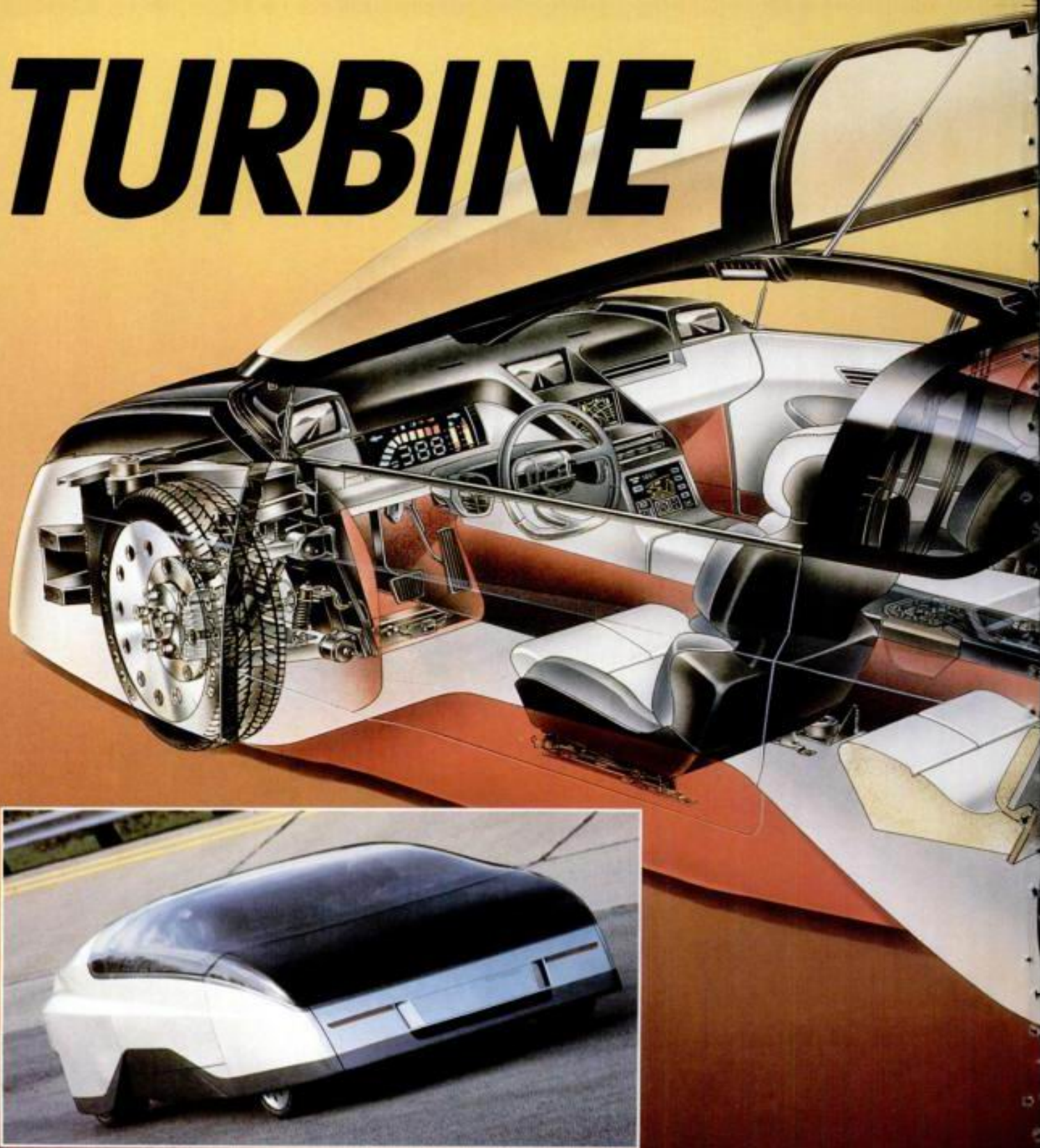
ity. And the Doppler radar system will locate unseen but dangerous microbursts (wind shear) in the vicinity of the flight [PS, March].

Fly-by-wire and fly-by-light control systems will reduce weight by eliminating control surface cables and pulleys. Electrohydrostatic actuators will make the heavy hydraulic plumbing networks unnecessary.

The passenger cabin will also be larger and more comfortable. Quick-change seat-pitch capability will allow unneeded seats to be compressed, permitting more space for the passengers. Flat-panel video screens on each seat-back means that everyone will finally be able to see the movie.



TURBINE



The highly aerodynamic gas-turbine-powered Chevrolet Express is capable of running at a sustained 150 miles per hour.

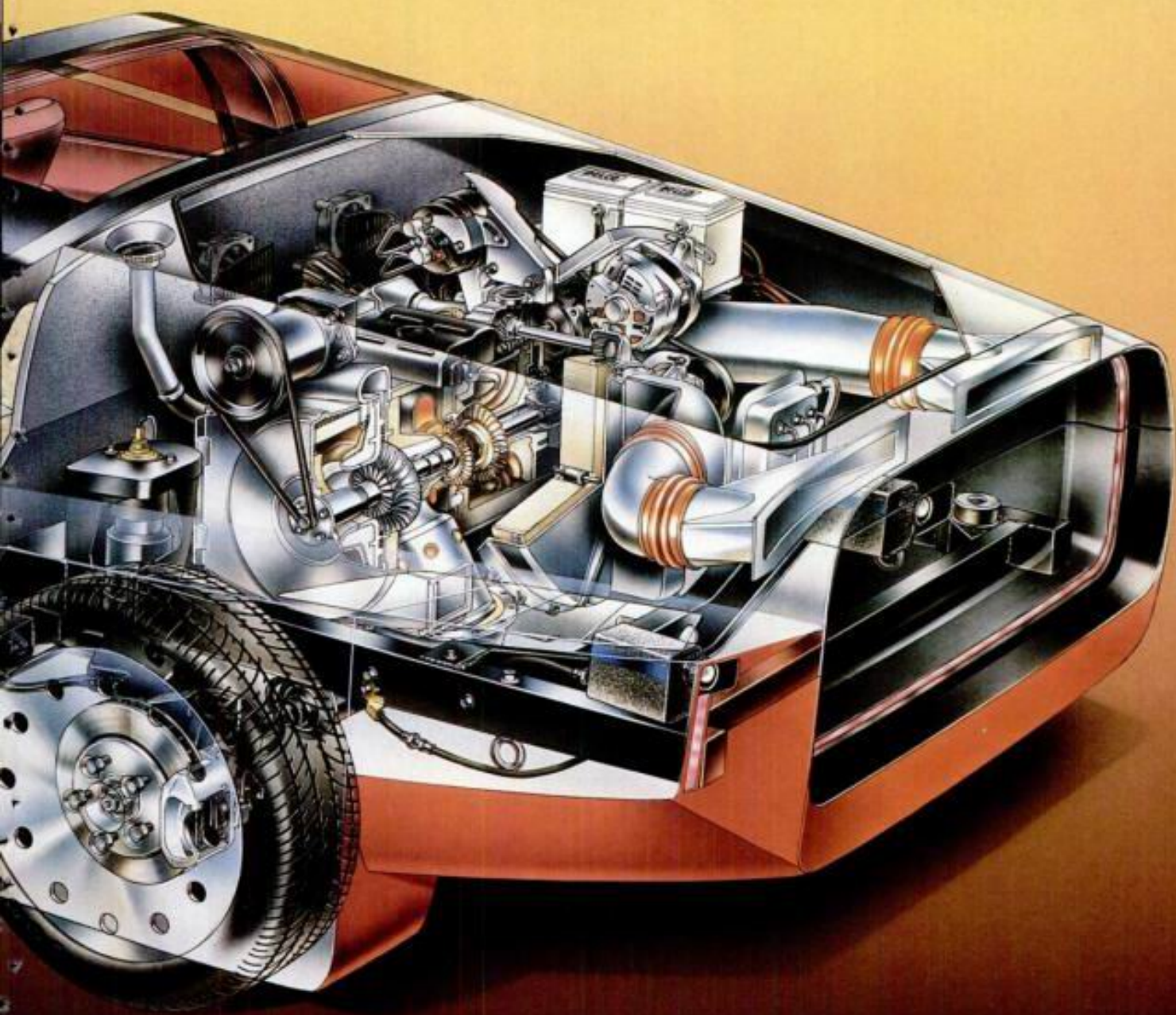
By **DAN McCOSH** *Detroit Editor*

Could a passenger car successfully compete with short-haul aircraft for high-speed, inter-city transportation? If speed were the only consideration, a few of today's high-performance sports cars could provide an affirmative answer. Even a Ferrari bogs down in traffic, however.

General Motors' Chevrolet-Pontiac-Canada (CPC) Advanced Engineering Department attacked the premise by visualizing a specialized, high-speed highway network built on abandoned railroad rights-of-way. Free of traffic and legal restraints, the Chevy Express would be capable of sustained 150-mph speeds while sipping about a gallon of kerosene every 20 miles.

That kind of performance would make an easy end run

TURN-ON



around most of today's congested air terminals. To achieve it, engineers and designers at GM's Advanced Concept Center in California and CPC's Advanced Engineering Department recently unveiled a slippery, four-passenger car powered by a rear-mounted gas turbine. In contrast to turbocharged engines, which enjoy tremendous popularity these days, pure gas turbines have generated little interest lately. But the Express is the latest in a long series of GM concept vehicles that have attempted to adapt the popular aircraft engine to an automobile.

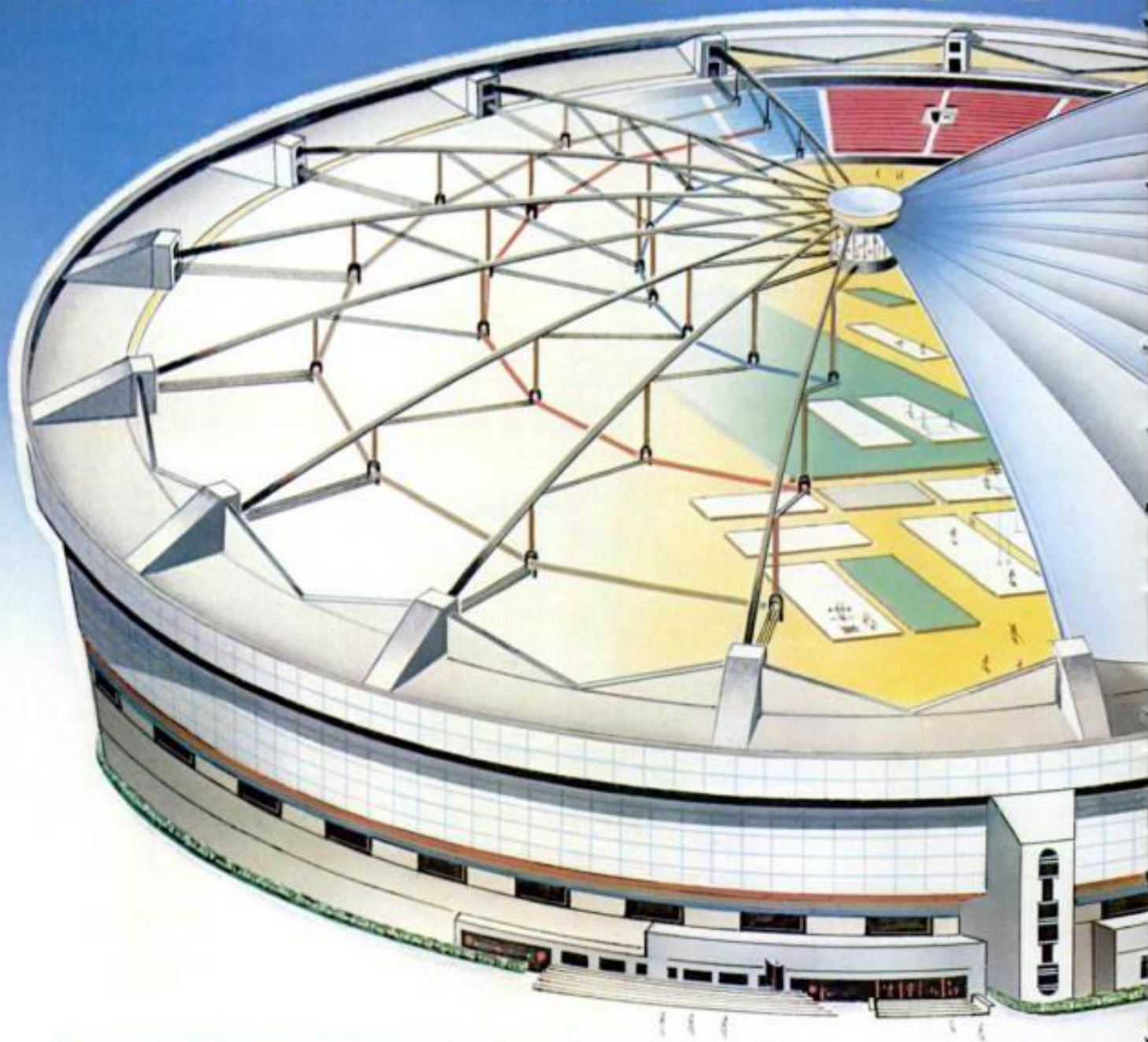
The Chevy Express is powered by GM's AGT-5, a gas

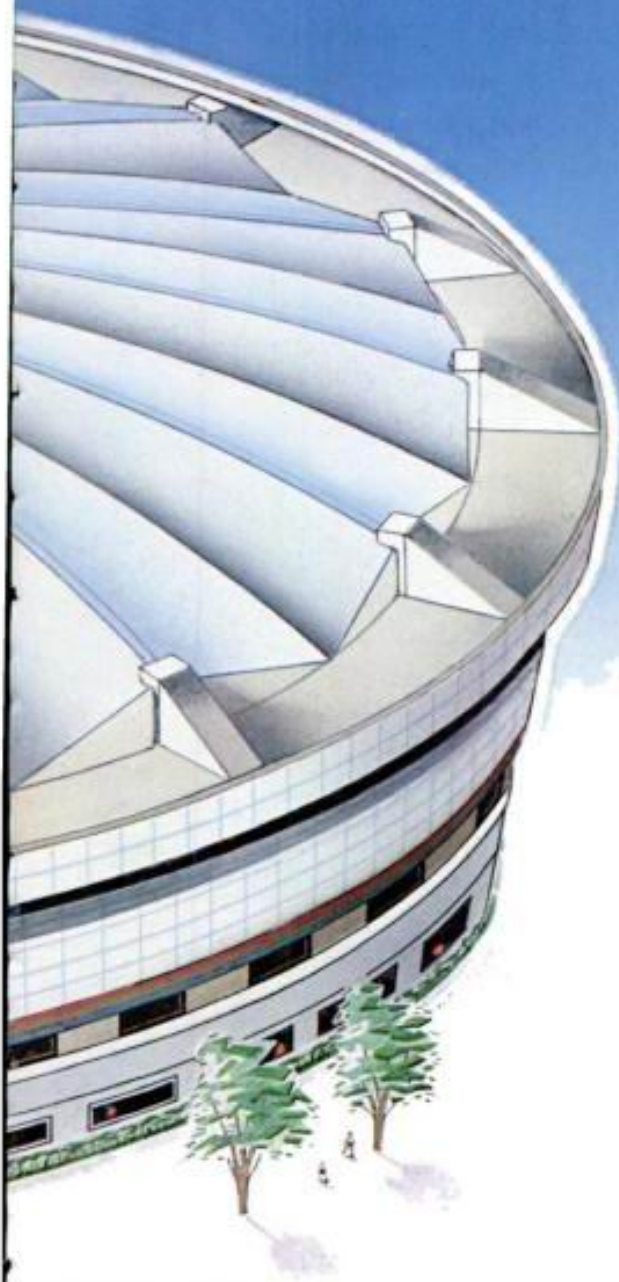
turbine that generates about 120 horsepower and 350 pound-feet of torque. A new ceramic regenerator is expected to boost the engine to about 150 hp later this summer, say GM engineers. A gas turbine works something like a jet engine blowing against a fan that drives the car's wheels. It is a continuous-combustion engine that burns with little pollution and provides ample low-speed torque.

GM has been showing experimental gas-turbine cars for more than 20 years, dating back to a 370-hp XP 21

Continued

Cable domes





Light, insulated fabric roofs create an airy, sunlit environment inside two arenas for the 1988 Olympic games in Seoul. Tensioned cables resist loading from snow or wind.

By **JOHN FREE**

Drawing by Walter Hortens

Just assembling these dome hoops is much more complicated," says design engineer David Geiger, flipping through stacks of large blueprints at his New York offices. Amidst designers hunched over computer terminals, Geiger is contrasting mechanical details of a monster 680-foot-diameter domed stadium being built in Saint Petersburg, Fla., with two smaller, less-complex domes completed in South Korea.

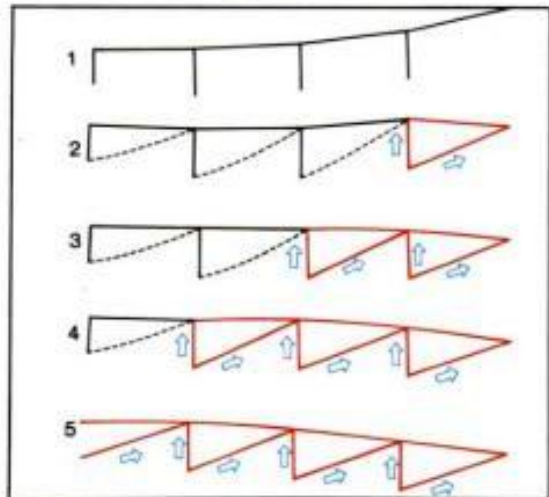
Geiger has a knack for creating striking new building structures. His firm, Geiger/KKBNA, has designed many giant fabric roofs supported entirely by air pressure produced by fans. Other tentlike buildings the firm has designed span more than 100 acres ["Tension Structures," July '81]. Geiger's latest roof design, the cable dome, will be widely seen during the 1988 Olympics in Seoul, South Korea, where fabric roofs cover a 13,000-seat gymnastic arena and 7,000-seat fencing stadium.

The need for a new type of roof emerged after the firm helped design a fabric-roofed sports center, shaped like half a football, in Canada. "I proved we could insulate a fabric roof," says Geiger, "and felt we had to find a way of using the insulated fabric on stadiums. I knew we couldn't do it with air support. It was a big impetus to come up with another way of spanning large spaces."

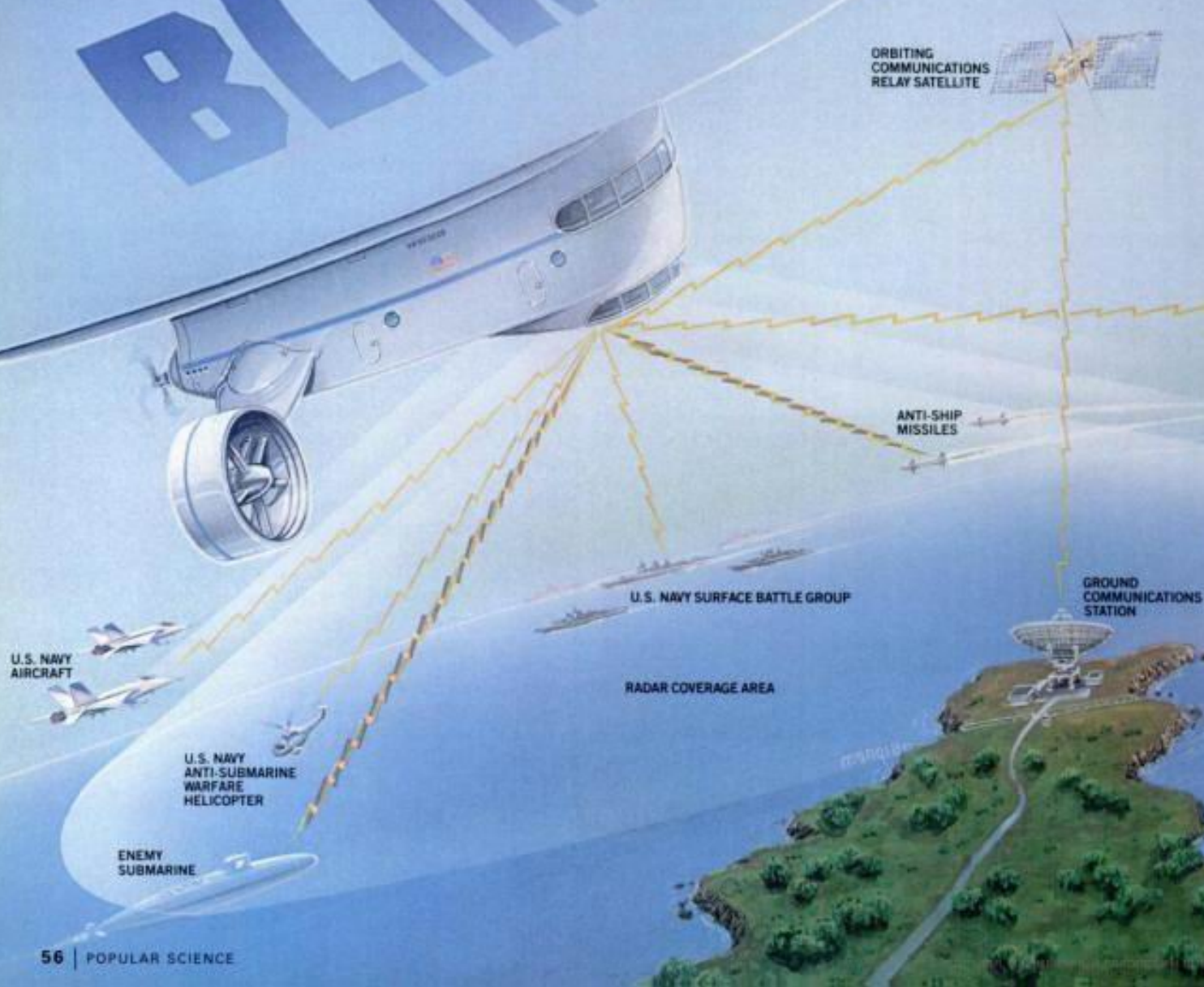
Geiger thought about R. Buckminster Fuller's idea—never realized—for a type of high-rise cable-supported dome that involved triangular-shape elements for structural rigidity. But Geiger felt he could avoid Fuller's more complex design and create a low-rise cable dome. "We defined a new structure that was not triangulated but had the same properties," he says.

Other advantages of Geiger's patented air-supported fabric roofs have been carried over to cable domes: "We have a very simple system of fabric clamps and panels attached to the main structure," says Geiger. So-called valley cables between the main cables pull the fabric taut. "That's what stretches the fabric and gives it structural rigidity as opposed to pressure in an air structure," he says. **ES**

Cutaway view is artist's concept of cable dome built for Olympic games in South Korea, revealing the tensioned cables, hoops, and vertical posts that support a fabric roof. One of the 16 main ridge cables is prominent in the photo (right). Ridge cables are formed by threading smaller strands through metal castings topped with small threaded studs that fit holes in the fabric sections. The cable network is assembled on the floor of the stadium, then elevated in stages, working from the perimeter inward. The diagram (left) shows a single ridge cable, vertical compression posts that link the cable to circular hoops, and four stages of tightening the diagonal cables to raise the cable network. Using hydraulic jacks beneath the compression posts, 32 workers—two on each ridge cable—tighten the diagonals simultaneously to keep the hoops level (photo, far left). Loads are carried from the central tension ring through the ridge cables, tension loops, and diagonal cables, until they are resolved in the perimeter compression ring—the concrete anchor points built into the stadium walls. Outer hoops require 40 strands of 0.6-in. steel cable in this dome but 135 strands for a 680-ft. dome underway in Florida. A multilayer fabric is clamped to ridge cables.



RETURN OF THE BATTLE BLIMPS



For years you've seen them floating high above football stadiums photographing games or advertising consumer products, but until 1962 helium-filled airships had a long history as military machines, too. It may happen again: The U.S. Navy plans to build a giant advanced-technology blimp designed to keep constant watch over the horizon for deadly sea-skimming missiles fired at naval surface vessels—a job patrol planes and helicopters can't do as well. If military airships make a comeback, can huge civilian passenger cruisers and heavy-lift cargo "skycranes" be that far behind?

By STEVEN ASHLEY

Illustration by Jeff Mangiat

SOUTH ATLANTIC OCEAN, MAY 4, 1982—The British destroyer H.M.S. Sheffield is on lonely radar picket duty in the choppy waters off the disputed Falkland Islands. Just out of the Sheffield's radar range, an Argentine Super Etendard fighter swoops down from a cloud-covered sky to launch a French-built Exocet anti-ship missile. The \$200,000 hunter-killer screams in six feet above the waves at almost the speed of sound. Eluding the Sheffield's electronic defenses, the aerial torpedo blasts into the \$100-million destroyer's hull. Within seconds black, acrid smoke smothers the deck and spirals skyward. The crew fights the raging blaze for five hours, then abandons the wreck. The surprise attack leaves 20 British seamen dead, 24 wounded, and naval planners worldwide scrambling to find an effective and economical countermeasure to lethal sea-skimming missiles.

Five years later, U.S. Navy Rear Admiral Robert L. Leuschner sits in a nondescript office building near the Pentagon pondering what may be an answer to the deadly menace: huge high-technology airships designed to chap-

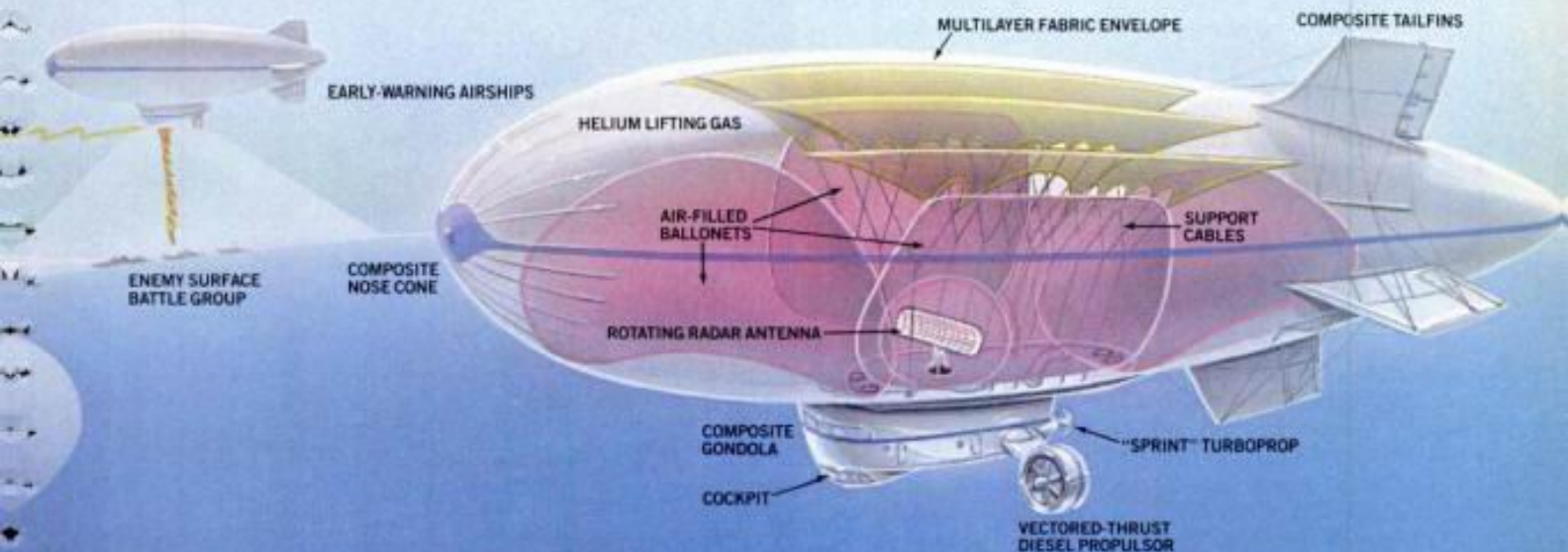
erone the surface Navy as it sails the seven seas.

"Of course, the common reaction is to giggle and say, 'Airships? You mean blimps? What a silly idea!'" the tall, white-haired, white-clad former carrier skipper tells me. "But what else can stay up in the air with a radar big enough to see these small objects against the ocean clutter?" he asks, gesturing with an unlit cornucob pipe. "Even with an aircraft carrier, we need everything to go just right with the long-endurance aircraft we have now—E2-C Hawkeyes—to maintain round-the-clock surveillance patrol. And a non-carrier battle group has little organic [intrinsic] detection capability against low-flying anti-ship missiles."

The admiral gazes for a moment out of a rain-swept window. "That's where airships come in," he continues, again flourishing the pipe. "Instead of hours of endurance, we're talking weeks."

Leuschner's vision may eventually give a new look to the future Navy. Today, 26 years after its last lighter-than-air craft was decommissioned, the Navy is taking the first steps toward what could be a return of the battle blimp and the Naval Airship Service. In a cavernous hangar in Weeksville, N.C., the first prototype gondola is already

Continued



The Sentinel 5000 will be the largest non-rigid airship ever constructed. The Navy plans to station the blimp 5,000 to 10,000 ft. above a naval surface battle group as a kind of "low-altitude satellite" to detect the approach of sea-skimming (Exocet-type) anti-ship missiles. Experts say that airships are the best aerial vehicle to perform this job because only they can economically maintain their station for extended periods. Once an incoming missile is located, surface ships can launch white-hot flares and reflective chaff to decoy the missile's infrared and radar sensors. If those countermeasures are ineffective, anti-missile missiles can be fired, and as a last resort, radar-

guided close-in-defense gun systems can throw a "wall of lead" in front of the approaching weapon.

The Sentinel 5000 will also be called upon to relay fleet communications over the horizon to distant ships in addition to serving as a battle-group operations control center. If blimps prove to be effective for these tasks, the Navy may use airships to conduct anti-submarine warfare missions with sonobuoys, dipping sonars, and lightweight torpedoes as well as anti-surface shipping targeting missions on enemy vessels lying far over the horizon.

Cutaway diagram of a blimp shows its major subsystems.

If blimps bounce back big, some experts say that huge rigid airships like the *Graf Zeppelin* of old may be in the offing because they have greater lift capacity than non-rigid airships. Rigid frames more efficiently distribute loads to the lifting gas. Under Navy contract, Boeing Military Airplane Co. engineers developed a plan to build a 520-ft. 4.2-million cu.-ft. semi-monocoque design with a pressurized stressed composite skin attached to a rigid composite frame.

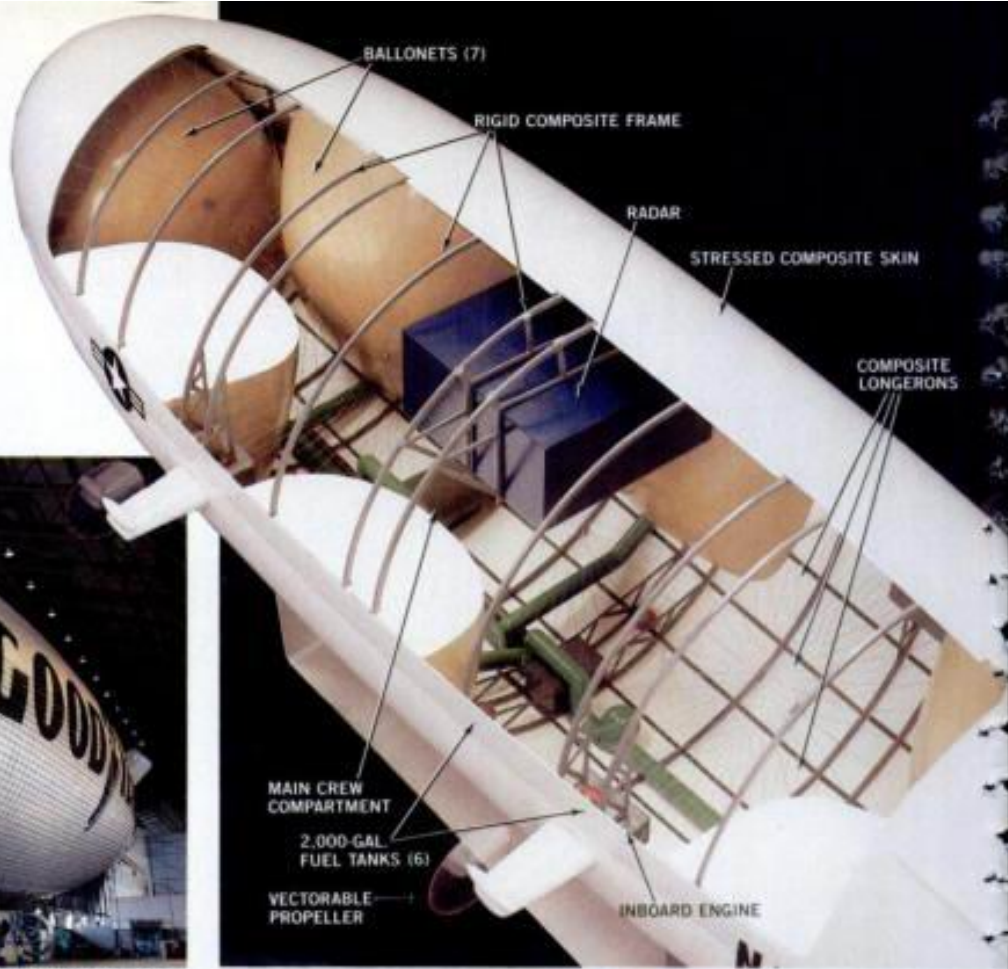


With a length of 205.5 ft. and a volume of 247,800 cu. ft. of helium, the Goodyear GZ-22 blimp *Spirit of Akron* is currently the world's largest airship. It features a nine-man composite cabin, vectored-thrust propulsion, fly-by-wire electronic flight controls, and a distinctive X-tail configuration that provides additional clearance when parking the ship in a hangar. The GZ-22 was developed as a modern replacement for Goodyear's advertising blimps, but was expected to be used also as a technology demonstrator.

taking shape. The completed blimp, to be called the Sentinel 5000, will be 423 feet long—half the length of an aircraft carrier. When its flexible fabric hull is filled with 2.35-million cubic feet of nonflammable helium gas, the new ship will be 60 percent more voluminous than the largest non-rigid airship ever built—the Goodyear Aerospace Co. ZPG-3W, a 1960s-vintage early-warning radar blimp.

The Sentinel 5000 will host a variety of high-tech features; among them: an advanced vectorable ducted-fan propulsion system for improved low-speed maneuverability; a pressurized gondola as wide as a 747's fuselage to keep the crew comfortable during month-long missions; modern non-metallic materials intended to minimize weight, the chances of detection by enemy radar, and electromagnetic interference; the latest in "fly-by-light" fiber-optic flight controls instead of heavy wire cables; a pneumatic actuator system linked by non-metallic air hoses to substitute for electric servomotors; and a 40-by-10-foot rotating radar dish designed to allow the blimp's radar system to spot small low-altitude targets more effectively than the powerful radar installed in Boeing E-3 Sentry Airborne Warning and Control System (AWACS) aircraft.

By late 1990, the big ship will be delivered to the Navy to begin a long series of field trials. If those tests are successful, the Naval Airship Program could lead to an entire armada of 40 or more even-larger missile-spotting guardian blimps. Beyond that, these next-generation



lighter-than-air craft could herald a new era of civilian passenger and load-hauling vehicles.

Even though the Navy disbanded the Naval Airship Service in the early 1960s, it hasn't totally ignored airships. "Since 1974, the Navy has been considering the blimp for various duties," says David Bailey, manager for lighter-than-air programs at the Naval Air Development Center in Warminster, Pa. "Over the years, we oversaw about forty research studies that analyzed and tested everything from subscale flying models to full-sized leased airships," he says. As anti-ship missiles steadily improved over the years, Bailey explains, the possible advantages of using airships against them became more and more apparent. By the middle of 1986, Leuschner's Naval Airship Program had been established, and the Navy had let the world's aerospace industry know of its new need. Long-time blimp builders, Goodyear Aerospace Co. (a former unit of The Goodyear Tire & Rubber Co.) and a relative newcomer from Britain, Airships Industries Ltd. (together with its American partner, Westinghouse Electric Corp.), submitted bids. To the surprise of many, Goodyear did not win, despite its long history as the supplier of Navy airships. Goodyear had proposed a highly modernized version of the ZPG-3W airship for the new mission. The winner of the \$169-million contract was Westinghouse-Airship Industries, an Anglo-American joint-venture firm based in Baltimore, Md. Airship Industries will build the blimp and Westinghouse Electric will install the radar system.

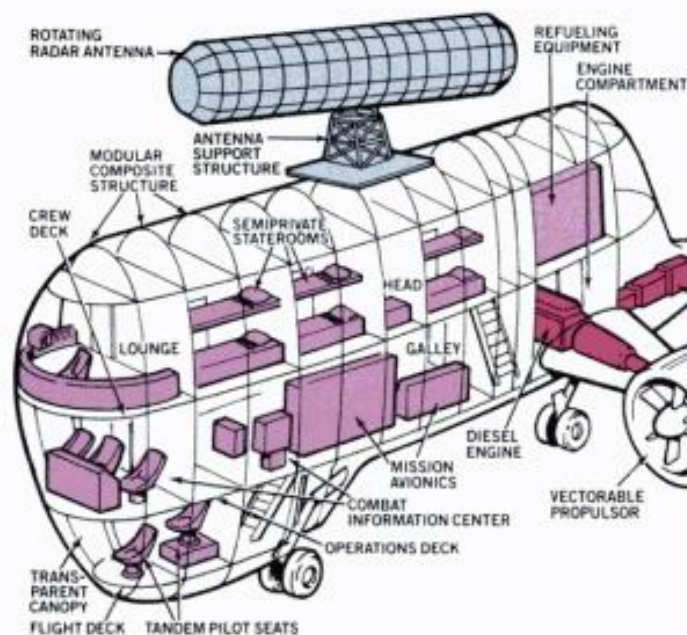
The Sentinel 5000 may not look wildly different from a traditional blimp—at least not from a distance. But under

its skin much will be changed. For example, its advanced vectored-thrust propulsion system "is the first really effective control system for airships," says Roger Munk, technical director for Airship Industries. "It will consist of two tilting propulsor ducts with 14-foot-diameter propellers driven by 1,800-horsepower CRM S.R.L. [Milan, Italy] marine diesels, and a single uncowed 1,800-horsepower General Electric CT-7 turboprop in a pusher configuration. The directed thrust it provides will allow the Sentinel 5000 to maintain station in a wide range of weather conditions."

"Our Skyships [the emerald-green Fuji blimp is one] pioneered this type of system," he says. "With them we were able to demonstrate how you can rotate the ducts upward and power the ship right down to the ground while keeping the craft level. This will be particularly important in the low-speed maneuvering necessary when the naval airship refuels at sea every three or four days."

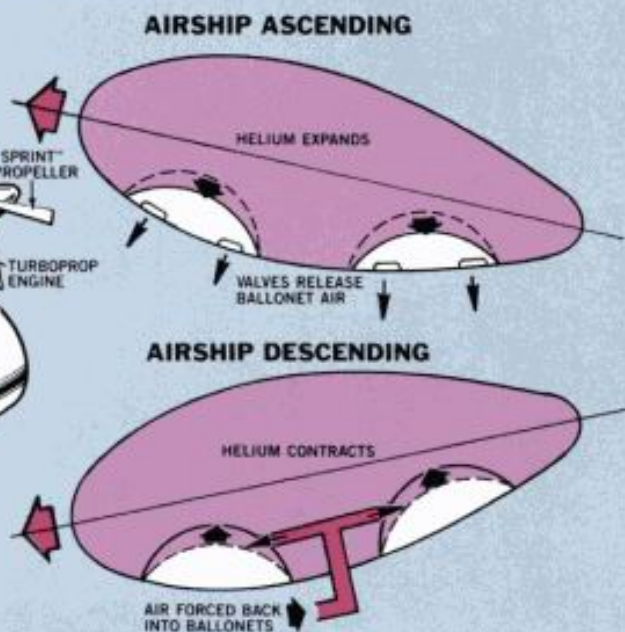
The real significance of this low-speed maneuvering capability becomes clear when you make a landing approach in a conventional blimp, as I did one summer afternoon last year in the Goodyear Airship *Enterprise*, with longtime airship pilot Pat Henry at the helm. After a delightful spin around New York Harbor, we're nearing our landing strip when suddenly, the entire cabin tips unsettlingly downward at what seems to be a 45-degree angle, and the ground starts to rush up at the windscreen. If this were a fixed-wing aircraft, I tell myself, we'd buy the farm for sure. But it's a blimp, and with a precise turn of the ship's wheel mounted beside his pilot's seat, Henry levels off

(Continued on page 108)



Construction in progress of a prototype gondola (left) for the Westinghouse-Airship Industries Sentinel 5000 airship at its Weeksville, N.C., facility. Composed of lightweight, but strong non-metallic composite materials, the 15-man, triple-decker gondola would be relatively invisible to radar. The 81-ft.-long pressurized gondola will be big enough to keep the crew comfortable on long missions. The cutaway view of the gondola (above) shows the crew accommodations and working areas as well as the radar antenna and support on the roof. On the top deck, there are 12 semi-private state-rooms, two heads, a lounge, and recreational facilities. The middle deck will include a galley, mission avionics equipment, combat-information center, as well as a non-pressurized engine compartment with its refueling and resupply apparatus. The mezzanine flight deck has tandem pilot's seats, flight controls (including a digital autopilot system), and navigation instrumentation.

How ballonets work



DRAWINGS BY ED LIPINSKI

Ballonets are pouches that can expand within the main airship envelope to maintain gas pressure on the external bag as atmospheric pressure changes with altitude. Sealed off from the helium lifting gas, ballonets can be filled with outside air through internal ducting and emptied through valves at their base. The valves open automatically on ascent to release air as the helium expands due to lower pressure at higher altitudes. On descent, the ductwork permits air to reenter the ballonets under fan pressure to avoid envelope collapse—especially under airflow pressure on the nose. Pairs of ballonets are installed fore and aft in airships to allow attitude control by filling the pouches differentially. An airship's operational ceiling depends on ballonet volume—this height limit is reached once they're empty.

BIG RIG

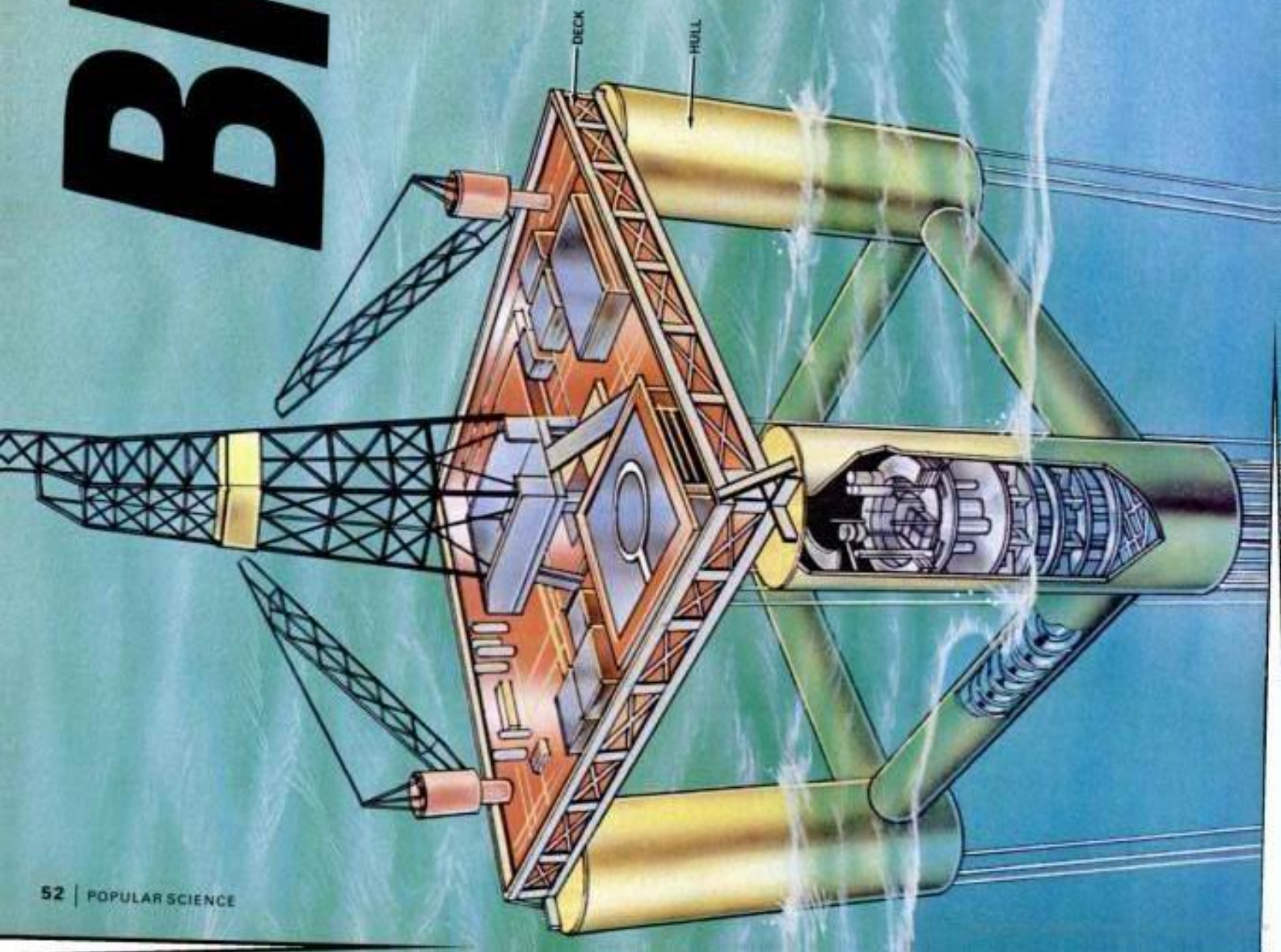
Anchored 1,760 feet down on the bottom of the Gulf of Mexico, this record-setting tension-leg platform will tap oil from beneath the sea floor. Unlike conventional platforms that sit atop underwater skyscrapers, this newest engineering marvel is anchored by gigantic steel mooring lines.

By **NAOMI J. FREUNDLICH**

Illustrations by Linda Richards

From a distance the new platform will look just like the others in a growing city of huge underwater skyscrapers that tap the oil-rich seabeds of the Gulf of Mexico. Clustered on the continental shelf, these platforms tap reserves in depths of water of around 1,000 feet. But next year, when tugboats haul Conoco Inc.'s platform into the Gulf, its destination will explain its unusual design. The platform, with its four huge hull columns churning the water, will move past the urban sprawl to new frontiers: the Green Canyon Block 184 oil field, about 170 miles southwest of New Orleans, where water depths reach almost 2,100 feet. When the platform is installed in 1,760 feet, it will be the world's deepest-ever design.

This Gulf of Mexico pioneer is a radically new kind of oil-production platform designed by Conoco to tap deeper reserves economically. Connected to the seabed by 12 tubular steel mooring lines, the platform's natural buoyancy creates an upward force, keeping the legs under tension and allowing it to stay in place in water up to 6,000 feet deep. The tension-leg platform (TLP) is stable and cost effective: It requires far less steel than fixed platforms; and with the help of agile remotely operated vehicles (ROVs), it's easy to maintain. But perhaps the most important aspect of the tension-leg design is its portability. Once a TLP's work is done in one oil field, it can be unlatched from its foundation and moved to another site. Achieving greater depths with the TLP design will require form and function.



the original design, only some strengthening of the tension legs.

Drilling deeper

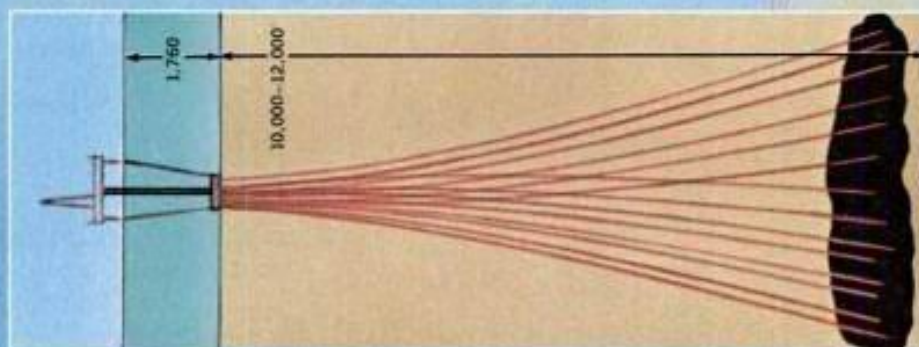
"About ten years ago our engineers saw that there were limits to how tall you could build a fixed platform," says Cor Langewis, an engineer and general manager for the Conoco project. That height seemed to be about 1,200 feet, with economics being the main limiting factor. Whereas a 1,760-foot rigid platform would require 80,000 tons or more of steel, the Gulf of Mexico TLP uses only 12,000 tons. And while assembling the fixed structure in deep ocean also jacks up construction costs, the more portable TLP is built on shore and transported to the site. The ultimate cost cutter, though, is the TLP's reusability. According to Langewis, moving a deep-water fixed platform (a giant steel latticework permanently piled into the sea floor) is impossible. "It's about as easy as putting the Empire State Building on wheels and carting it across town," he says.

Another deep-sea option, the submerged production system, where oil wells sit on the sea floor and all production equipment is placed on a floating drilling rig, is also less desirable in these lean times ["Wave-Challenging Giant Rigs," Jan. '81]. Says Langewis, "With these systems your operating costs are high because all well work is done underwater."

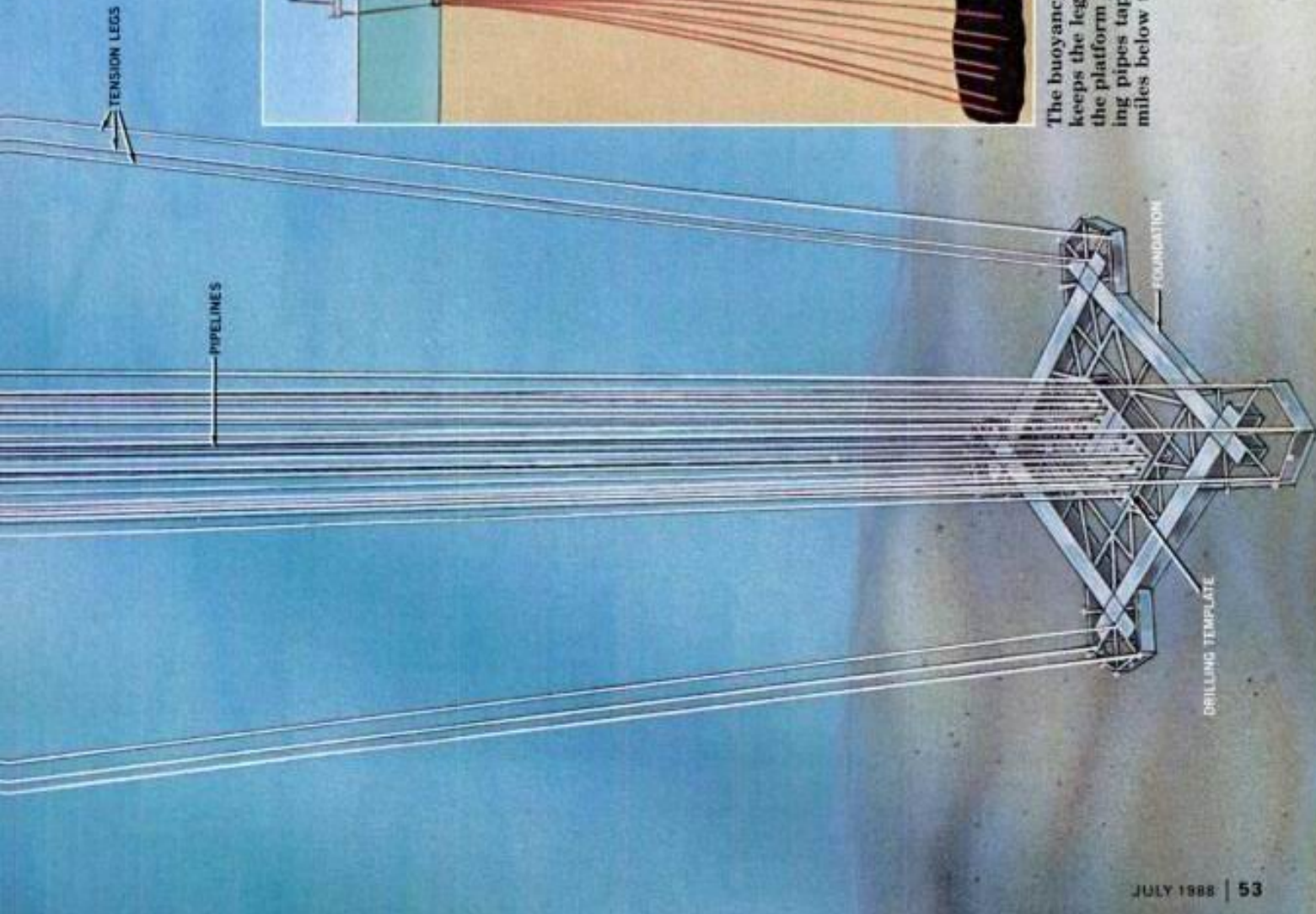
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A 310-ton steel drilling template (above) was installed at the Gulf platform site in June 1987. Engineers made a final inspection of the structure before installing it at a depth beyond the range of human divers. The installation took three weeks and required the help of a semi-submersible rig to position and sink the template and remotely operated vehicles to secure it to the sea floor. Five of 16 oil wells have already been drilled through the template holes; the rest will follow later this year.



The buoyancy of the platform keeps the legs taut and holds the platform in place. Collecting pipes tap oil located two miles below the seabed.



MISSILE

Proponents of the Pentagon's Strategic Defense Initiative say satellite-launched projectiles could knock out most nuclear missiles before they reach their targets. But some experts feel this element of the "Star Wars" program is overpriced and unworkable. The practicality of this complex technology may not become clear for a decade or more.

By **JIM SCHEFTER**

Illustrations by Dennis M. Davidson

Defcon one! Defcon one!"
"Arm the platforms."
"Platforms armed. Scanners active. We have eighty-four in the envelope."

"They're launching! Bad guys in all sectors... Beast says launches are confirmed."

"Turn 'em loose! Twenty more platforms coming over the horizon. They'll try for the strays."

Six hundred miles up, dotting the black sky from horizon to horizon above Soviet intercontinental missile fields, 84 U.S. satellites—space-based interceptor platforms—prepare to disgorge their loads of five-foot-long missile killers.

Data streaming down from a geostationary boost surveillance and tracking satellite (BSTS, or "beast") feed target coordinates and trajectories to each platform's battle-management computer. Seconds later, with climbing Soviet missiles in their sights, the interceptors fire their small and extraordinarily powerful rocket engines.

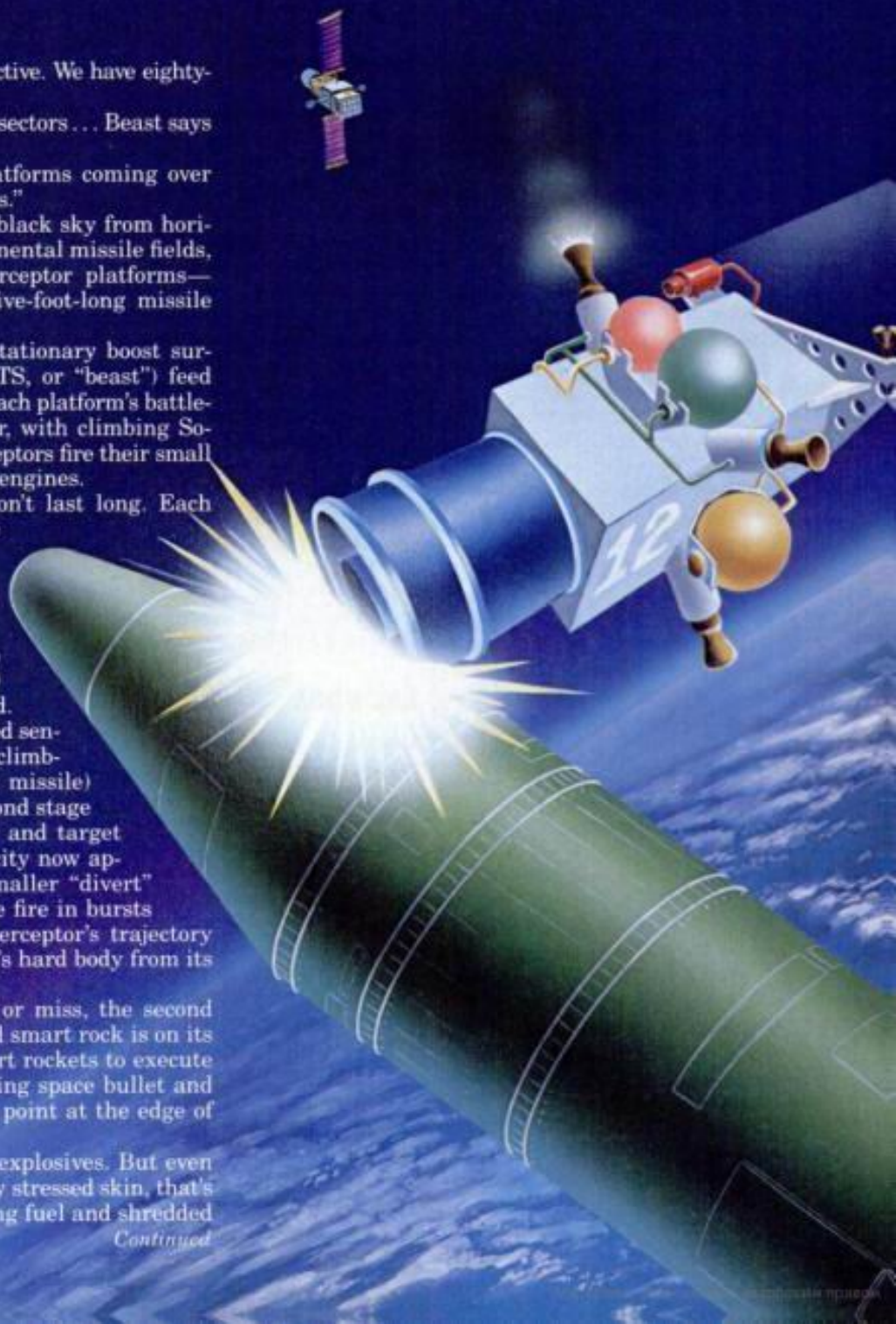
Now the chase is underway. It won't last long. Each interceptor is a multi-stage missile topped by a "smart rock," or kinetic-kill vehicle. Accelerating to incredible speeds—the numbers are classified, but the first stage probably goes from zero relative velocity to more than 6,000 mph in under 30 seconds—the missiles race downward.

Centered in an interceptor's advanced sensor eyes, the fiery exhaust plume of a climbing ICBM (intercontinental ballistic missile) glows intensely. The interceptor's second stage kicks in and the gap between killer and target shrinks dramatically as closing velocity now approaches seven miles per second. Smaller "divert" rockets bristling from the kill vehicle fire in bursts like machine guns, nudging the interceptor's trajectory as its sensors discriminate the target's hard body from its plume.

With only moments left until hit or miss, the second stage separates, and the oddly shaped smart rock is on its own. There's barely time for the divert rockets to execute their final corrections before the diving space bullet and the climbing ICBM reach a common point at the edge of the atmosphere. Then it's over.

The kinetic-kill vehicle carries no explosives. But even if it only grazes an ICBM's thin, highly stressed skin, that's more than enough. A rage of exploding fuel and shredded

Continued



KILLERS



The SDI program aims to defeat ICBMs by several means. Laser and particle-beam weapons and electromagnetic rail guns are some of the systems now being developed in research laboratories. The scenario above depicts the SDI element that is nearest to being built and put into service—a space-based missile-interceptor system. Here's how it's designed to work: When hostile ICBMs are launched, scores of sensor-equipped orbiting platforms detect the fiery plumes emitted by their rocket engines. Each platform disgorges a flock of small rocket-propelled interceptor craft that home in on the climbing missiles. As an interceptor approaches

a target, its rocket-booster stage separates, leaving only a kinetic-kill "smart rock" to pursue the ICBM. The interceptor's nonexplosive warhead uses small "divert" rockets to fine tune its trajectory toward a devastating collision with the missile. ICBMs that survived attack by interceptors during their first few minutes of flight would be attacked by a second wave of interceptors launched from platforms maneuvered to catch the missiles' multiple warheads during their mid-flight phase. Other SDI elements would be required to deal with the estimated 10% of the warheads the system's designers predict would elude the interceptors.

DAVIDSON 1988

Wave-driven air turbine

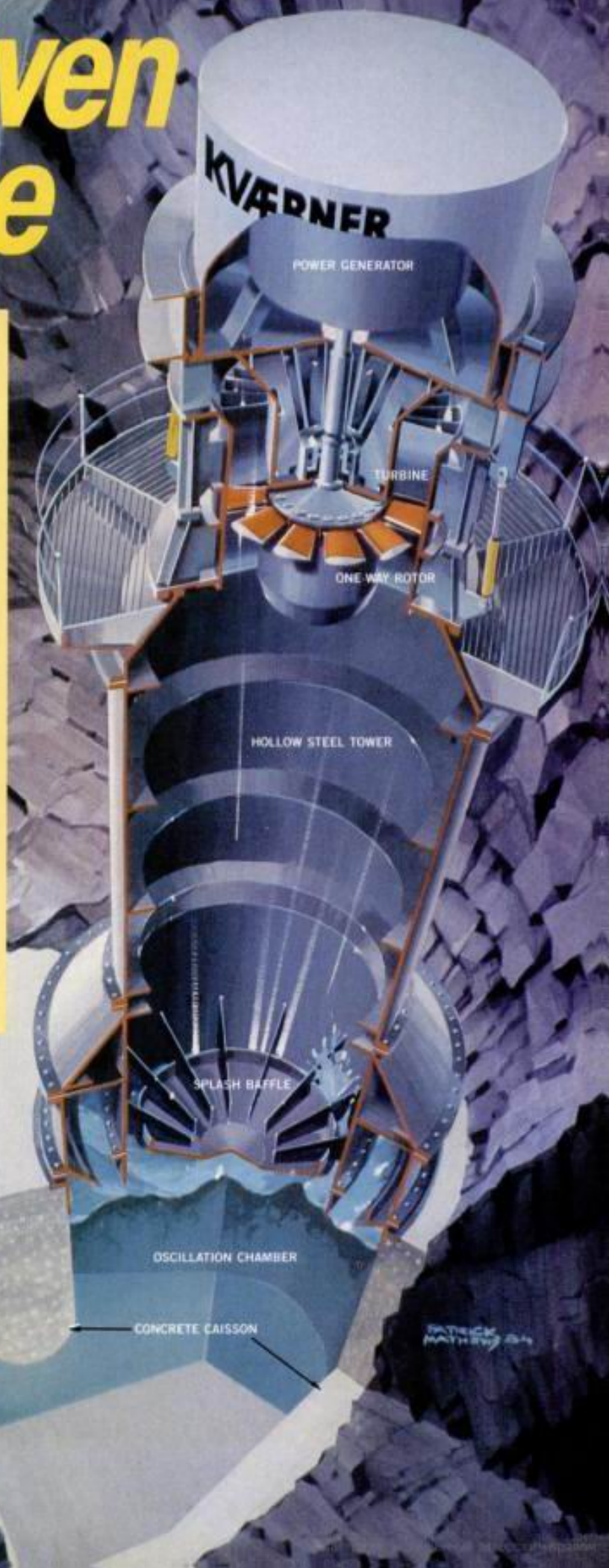
In Norway, a wave-powered water column oscillates inside a tower and forces air through a turbine generator. The ram-air concept may produce cheap electricity for coastal areas.

By DAVID SCOTT

Above the boiling surf that pounds the snow-dusted cliffs lining the Norwegian coast at Tostestallen rises a tower resembling a squat lighthouse. Nestled in a recess blasted from the rock of the near-vertical cliff face, the gray structure seems poised to warn mariners of the coastal hazard. But the 64-foot-high cylindrical tower is no lighthouse or beacon; it is a new kind of power-generating station. And it's not warning passing ships away from the powerful breakers; it's absorbing their wave energy and converting it to electricity.

Norway's wave-driven power tower on the Atlantic coast represents an innovative and potentially economical method to tap the ocean's vast energy resources. The 500-kilowatt pilot plant was designed and built by Kværner Brug, an Oslo-based company that is the leading producer of hydroelectric equipment in a country that relies on hydropower.

Ram-air generator tower stands in recess blasted from coastal cliff face near Bergen, Norway. Its hollow concrete base with submerged seaward opening is "tuned" to maximize absorption of wave energy. Turbine driving 500-kW AC generator has fixed blades profiled for one-way rotation regardless of airflow reversals as oscillating water column rises and falls. Baffle protects topside equipment from splashing water.



Rutan's tandem-wing transport



Aircraft engineer extraordinaire Burt Rutan has designed an unusual tandem-wing composite airplane to fill the Pentagon's need for a low-altitude long-range airlifter with short takeoff and landing capabilities. The proposed Advanced Technology Tactical Transport will ferry troops and materiel to remote unimproved airstrips and back.

By JIM SCHEFTER

MOJAVE, CALIF.

The chilly high-desert air was wrapped in an ice-blue January sky. Rows of derelict Convair 880s squatted in the dry distance, forlorn

relics condemned to play antique audience to the day's event.

The human audience, not so antique, and a mixed bag of U.S. Air Force blue suiters, aerospace executives, airplane enthusiasts, and reporters crowded to the edge of the runway.

They leaned forward suddenly, raising cameras, binoculars, and expectations as the twin turbines of the exotic double-winged aircraft spooled up to brake-release speed.

Then the mini-transport began to
Continued



PLASTIC PLANE—Fabricated of lightweight but stiff resin-composite materials, Scaled Composites' Advanced Technology Tactical Transport (AT³)

—shown here under construction—was built and flown in less than two years by a team of about 16 engineers and shop technicians.

move. Like an Olympic hurdler charging out of the blocks and through the tape, it burst past the earthbound observers. Quick-eyed witnesses saw the extended fast-acting wing flaps deflect downward in an instant. A moment later Burt Rutan's Advanced Technology Tactical Transport (AT³) leaped into the air, pointed its tapered nose sharply up, and then banked left into a steep climbing turn.

Cheers and yells followed in the wake of its upward arc, joined by speculation that the subscale ship easily broke ground in less than the predicted 1,000-foot takeoff roll. "This is dynamic testing with the pilot in the loop," Rutan said later, after the AT³ completed a series of low-level passes, then landed and stopped in just about no distance at all. "That's the approach we take in addressing new aerodynamics."

New aerodynamics is Rutan's stock in trade. Now the reigning wizard of advanced aircraft design—his canard-based fliers include speedsters like the VariEze and Long Ez [Nov. '78; May '82], the world-circling *Voyager* [Sept. '84], and Beechcraft's Starship corporate craft [June '84]—was using his fertile imagination and skills with composite fabrication to brush aside convention with a new kind of military transport built for the Defense Advanced Research Projects Agency (DARPA).

The Pentagon sought the AT³ to fill a gap between transport helicopters and much larger C-130 fixed-wing

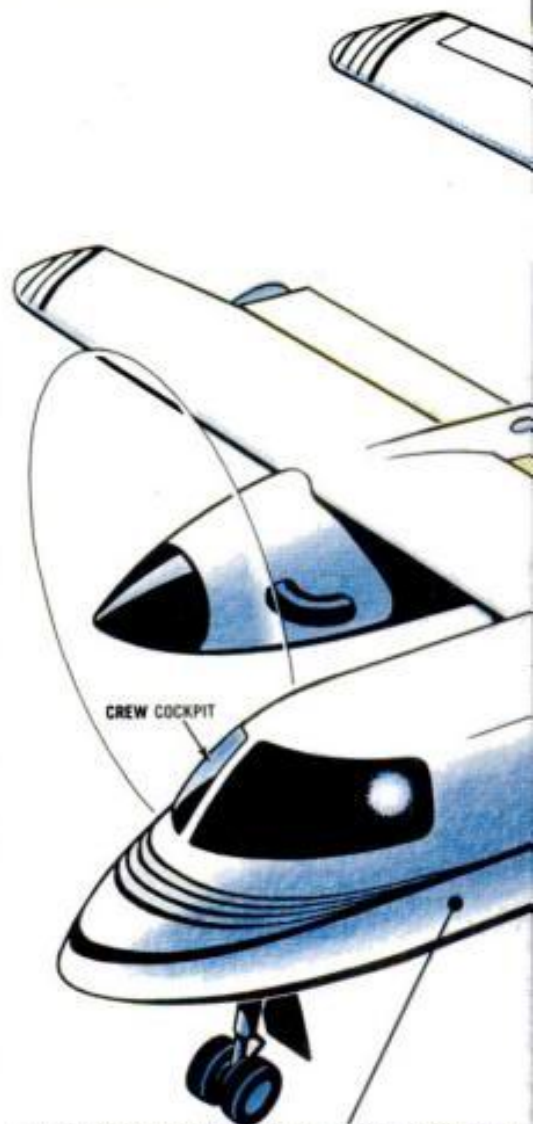
cargo planes: missions in which aircraft are required to make long-range, low-level, in-and-out excursions to deliver up to 14 troops or 5,000 pounds of cargo to remote sites with short runways. With a round-trip range of 2,400 miles and a top speed of 380 mph, it would be ideal for small-scale covert operations and rescue or resupply missions in hostile territory. Such missions now are handled by a heterogeneous fleet of C-130s, Beechcraft King Airls, and large choppers.

Bundle of innovations

"The AT³ is a bunch of little pieces of innovative design and technology that all go together," said Col. Doc Dougherty, DARPA's program manager. "It's also an experiment in prototyping. People have been saying that we need to do more of that."

In the prototyping approach to aircraft development, the Pentagon sets general guidelines for an airplane—its mission, size, approximate speed, and other factors—then lets an aerospace company design, build, and test an aircraft that meets them. It doesn't define the aircraft down to the last nut and bolt, and then ask competing contractors to submit detailed designs. The procedure was used successfully in developing the Air Force's F-16 fighter.

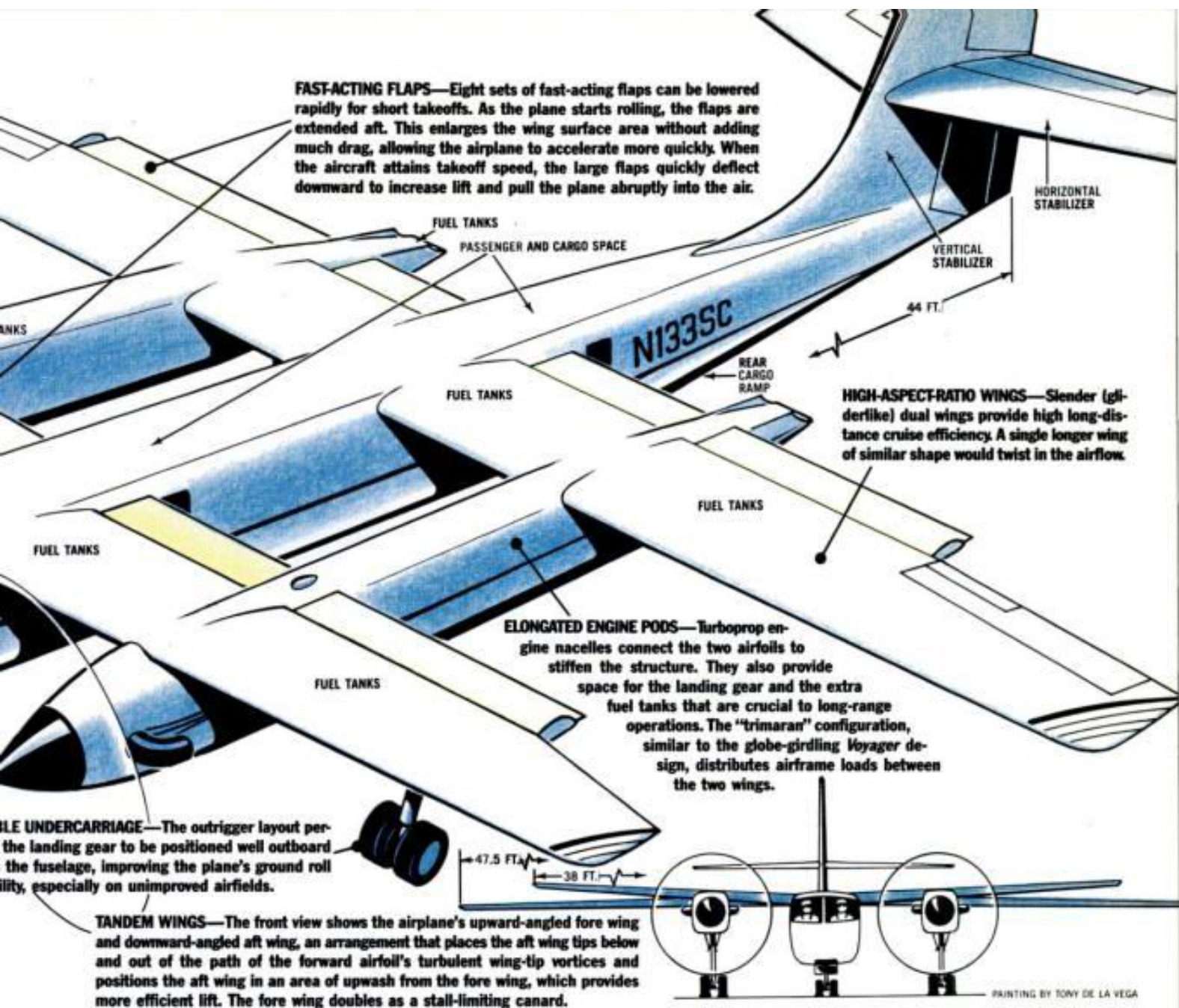
"You couldn't prototype an expensive and highly complex aircraft like the B-1 bomber," Dougherty said. "At the upper cost end, prototypes don't make a lot of sense." The reasons: Detailed design is required early on



ALL-COMPOSITE CONSTRUCTION—Glass and carbon fibers embedded in an epoxy-resin matrix make up most of the airplane's structure. Besides reducing weight, the use of composites permits the rapid reconfiguration of components during testing. Metal components would take much longer to remanufacture.

to avoid mistakes that could cause cost overruns, and coordination among many contractors on large projects is difficult. "But for lower-cost aircraft," Dougherty continued, "building a prototype or proof-of-concept airplane seems to work."

Working under a unique contract from DARPA that allowed Rutan's Scaled Composites, a subsidiary of Beech Aircraft Corp., to operate more independently than larger aerospace companies working on Pentagon projects, the small firm built and flew the AT³ in less than two years. "We did it with only about sixteen people," Rutan told me in an exclusive interview, "about one-third of them engineers and two-thirds shop people." Burdensome regulations are symptoms of a "can't do" attitude, he opined. "I want to make decisions quickly. Every day at four p.m. we all stand in a circle and decide what we're going to do in the next twenty-four hours. You'd be surprised at how fast you can move things along that way."



At even a casual glance, the AT³ is different. It's small—built at 62 percent of full-scale design size. And it's smooth. Rivets and skin joints are completely absent. In typical Rutan fashion, there's very little metal in its wings or body. Instead, all major assemblies are formed from composites of glass and carbon fibers and epoxy resin. That reduces the AT³'s empty weight to less than 6,000 pounds, smoothes the airflow over its surface, and gives the structure an incredible strength.

A roundly tapered and sloped nose blends smoothly into an immense bulging windshield, which in turn curves back into the fuselage, giving the two-man flight crew extraordinary visibility. The 44-foot fuselage itself is a flattened tube that sits low to the ground.

In the style of much larger military transports, the underfuselage of the subscale craft angles up to the tail to accommodate a rear cargo ramp. The tail assembly is almost traditional,

with elevators mounted nearly halfway up the vertical stabilizer, which tops out at 14 feet.

But it's the wings that catch your eye. There are two, one behind the other, mounted high on the fuselage and connected by elongated pods. Each pod holds a 750-horsepower Pratt & Whitney Canada turboprop engine positioned ahead of the forward wing, a retractable landing gear strut in the space between wings, and a fuel tank. The tandem wings also are "wet," but rather than fuel, they're filled with water for ballast. To explain: In the full-scale version the wings would carry aviation fuel, but for simplicity's sake the fuel-line plumbing in the subscale model's wings were omitted. Hence the subscale plane holds fuel only in its nacelle tanks. This power plant and fuel tank package gives Rutan's test ship a top speed of about 345 mph and a range of slightly more than 1,000 miles.

The 38-foot-long front wing, which angles upward a bit more than the

rear, doubles as a canard. The rear wing, with a 47½-foot span, extends about five feet farther out on either side. Both gliderlike wings have slender high-aspect-ratio shapes that provide good long-range flying efficiency. When the AT³ banked and turned during its demonstration flight, the wings looked like two Popsicle sticks glued across a paper tube.

But the high-aspect-ratio airfoils raise a problem: "Slender wings aren't very strong when twisted," Rutan said, "so to support the loads from fuel, engines, and landing gear we have two wings connected by the pods."

Rutan's approach is radical. "To make a long, skinny wing work, you need a lot of lift, but not much weight," Dougherty said. "So what Burt did was to put the engines, landing gear, and fuel out there to distribute weight along the wing."

"But when you do that, the wing has to be stiff enough to withstand the loads," Dougherty explained. "So his

[Continued on page 106]



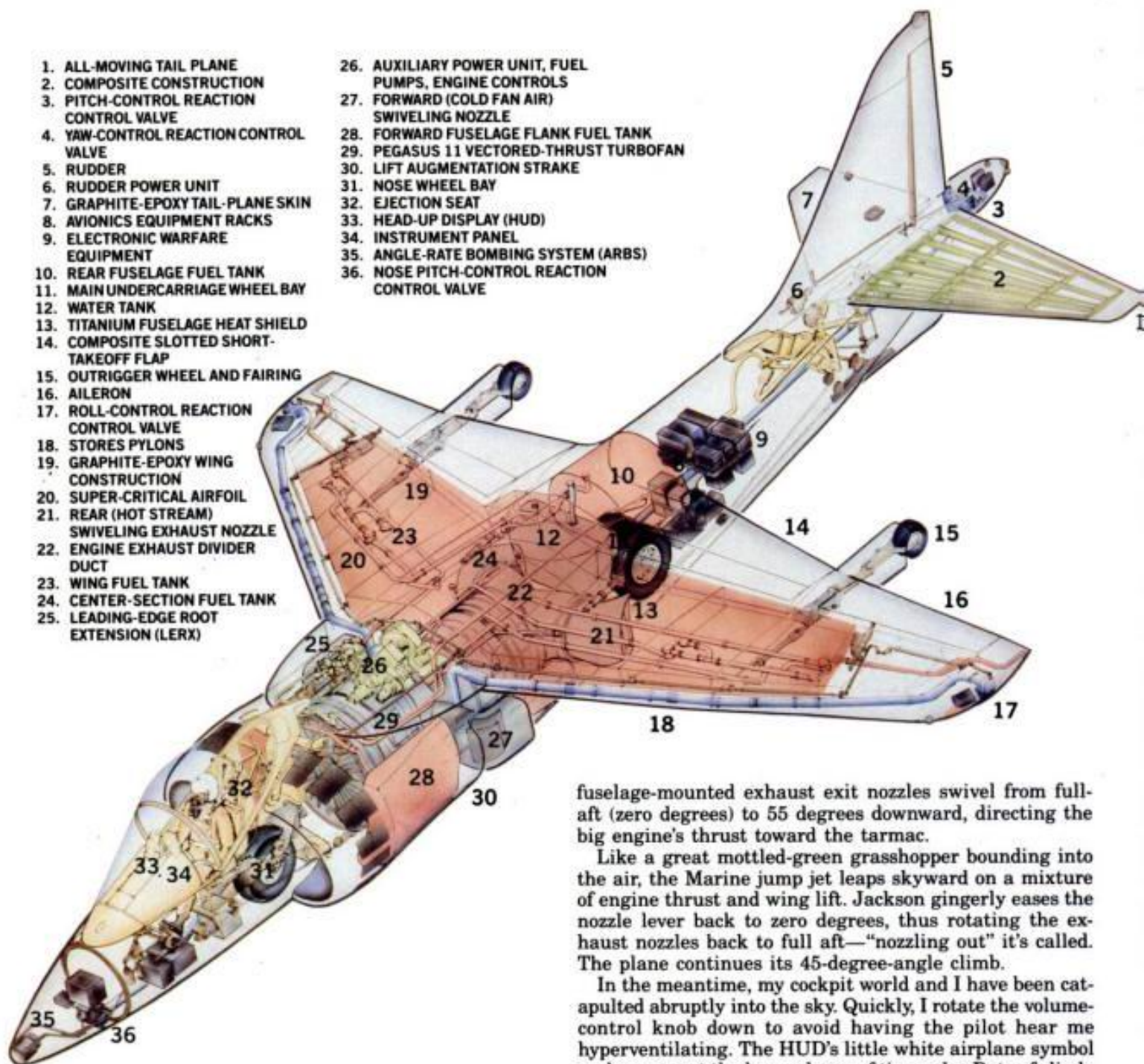
Piston-powered plane ▲

Powered by two Nissan six-cylinder turbocharged engines, the Pond Racer will approach 600 mph, says designer Burt Rutan of Scaled Composites. Named after Bob Pond of Advance Machine Co., it's made almost entirely of graphite—a material never before used in a production aircraft.

Jet stream adds maneuverability ▼

Twin jets give this 450-passenger Swedish ferry a top speed of about 28 mph with low vibration and noise levels. Nozzle valves redirect the flow to give stepless speed control, from full speed ahead to full speed reverse. MarineJet Power Systems, Box 130, 742 00 Osthhammer, Sweden.





1. ALL-MOVING TAIL PLANE
2. COMPOSITE CONSTRUCTION
3. PITCH-CONTROL REACTION CONTROL VALVE
4. YAW-CONTROL REACTION CONTROL VALVE
5. RUDDER
6. RUDDER POWER UNIT
7. GRAPHITE-EPOXY TAIL-PLANE SKIN
8. AVIONICS EQUIPMENT RACKS
9. ELECTRONIC WARFARE EQUIPMENT
10. REAR FUSELAGE FUEL TANK
11. MAIN UNDERCARRIAGE WHEEL BAY
12. WATER TANK
13. TITANIUM FUSELAGE HEAT SHIELD
14. COMPOSITE SLOTTED SHORT-TAKEOFF FLAP
15. OUTRIGGER WHEEL AND FAIRING
16. AILERON
17. ROLL-CONTROL REACTION CONTROL VALVE
18. STORES PYLONS
19. GRAPHITE-EPOXY WING CONSTRUCTION
20. SUPER-CRITICAL AIRFOIL
21. REAR (HOT STREAM) SWIVELING EXHAUST NOZZLE
22. ENGINE EXHAUST DIVIDER DUCT
23. WING FUEL TANK
24. CENTER-SECTION FUEL TANK
25. LEADING-EDGE ROOT EXTENSION (LERX)
26. AUXILIARY POWER UNIT, FUEL PUMPS, ENGINE CONTROLS
27. FORWARD (COLD FAN AIR) SWIVELING NOZZLE
28. FORWARD FUSELAGE FLANK FUEL TANK
29. PEGASUS 11 VECTORED-THRUST TURBOFAN
30. LIFT AUGMENTATION STRAKE
31. NOSE WHEEL BAY
32. EJECTION SEAT
33. HEAD-UP DISPLAY (HUD)
34. INSTRUMENT PANEL
35. ANGLE-RATE BOMBING SYSTEM (ARBS)
36. NOSE PITCH-CONTROL REACTION CONTROL VALVE

the speedometer as well as the road up ahead. In addition to digital readouts indicating airspeed, heading, altitude, rate of climb, g forces, and distance to navigation way points, the holographlike image shows rows of tic marks Jackson calls a flight path/pitch ladder. There's a small white airplane symbol—he calls it the velocity vector—in the center. It reminds me of a video-game screen... except that this game is for real.

Emerging from my split-second reverie, I manage to respond, dredging up my best Chuck Yeager-imitation drawl: "All set. Let's go."

"OK. Here we go!" the squawk replies. I grab for the lip of the cockpit's side walls.

Up front, Jackson makes a final check to see whether the Harrier's oversize and slotted high-lift STO wing flaps are in position. Then he simultaneously releases the brake and slams his throttle lever forward to full power. With a start, the Harrier accelerates down the runway, forcing me into my seat. When the HUD's airspeed indicator reads 83 knots (as slow as some Cessnas, he notes), Jackson pops the nozzle angle lever to the preset STO stop position and pulls back on the control stick. In unison, four

fuselage-mounted exhaust exit nozzles swivel from full-aft (zero degrees) to 55 degrees downward, directing the big engine's thrust toward the tarmac.

Like a great mottled-green grasshopper bounding into the air, the Marine jump jet leaps skyward on a mixture of engine thrust and wing lift. Jackson gingerly eases the nozzle lever back to zero degrees, thus rotating the exhaust nozzles back to full aft—"nozzling out" it's called. The plane continues its 45-degree-angle climb.

In the meantime, my cockpit world and I have been catapulted abruptly into the sky. Quickly, I rotate the volume-control knob down to avoid having the pilot hear me hyperventilating. The HUD's little white airplane symbol rushes up past the long column of tic marks. Rate of climb: 12,000 feet per minute. Plastered back into the seat as I am, there's not much else to do besides hold on and watch. And the view through the raised cockpit's domed canopy is breathtaking. Visibility is excellent; it's almost as if you're flying without an airplane around you.

In a half minute the plane breaks through the cloud cover and into dazzling sunlight. Jackson levels off. Looking down, I can still see the airfield about a mile below. Some escalator ride, I decide. Relaxing a bit, I realize that I've got a death grip on the cockpit walls. Jackson checks in while I work to disengage my cramped hands: "You know, Steve, no other airplane in the world can take off like that... Steve? You OK...?"

In the early 1980s the U.S. Marine Corps embarked on a \$4.5-billion program to purchase over 300 AV-8B Advanced Harrier IIs from the joint manufacturers, McDonnell Douglas Corp. and British Aerospace Ltd. It would like to have more. The ability of this second-generation STO/VL bomb truck to get aloft from a short (less than 1,000-foot-long) airfield, deliver up to 9,200 pounds of ordinance with extreme accuracy, and then land vertically on an unimproved forward site for rearming and refueling makes it valu-



Agile aircraft ▲

Artist's concept of British Aerospace's Small Agile Battlefield Aircraft (SABA) shows a large canard, contrarotating prop fans, and two rudders—dorsal and ventral. Designed to attack low-altitude targets like combat helicopters, tilt-rotor aircraft, and cruise missiles, SABA must turn 180° in 5 sec. at combat speeds.



Hybrid train ▲

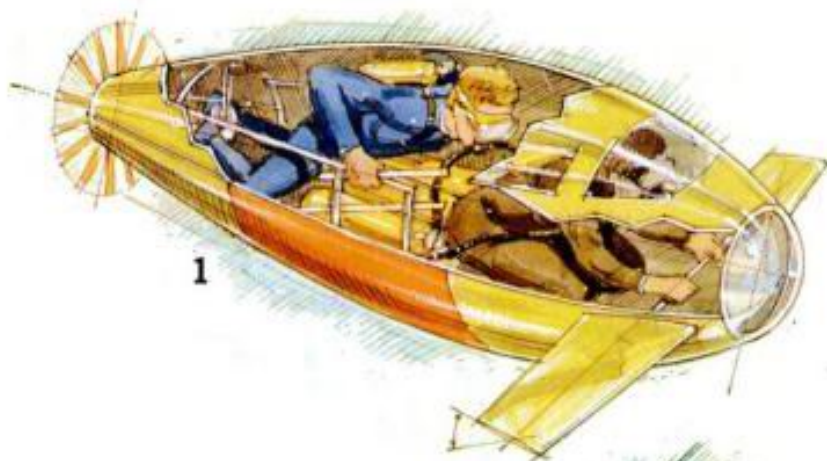
A linear motor propels the Limtrain along a center rail, but the train is supported by iron wheels, rather than by magnetic levitation. It's the first motor car of its type in Japan, says Mitsubishi Heavy Industries, the builder. The Limtrain carried passengers on trial runs at the '88 Saitama Expo in Kumagaya City.

Special delivery ►

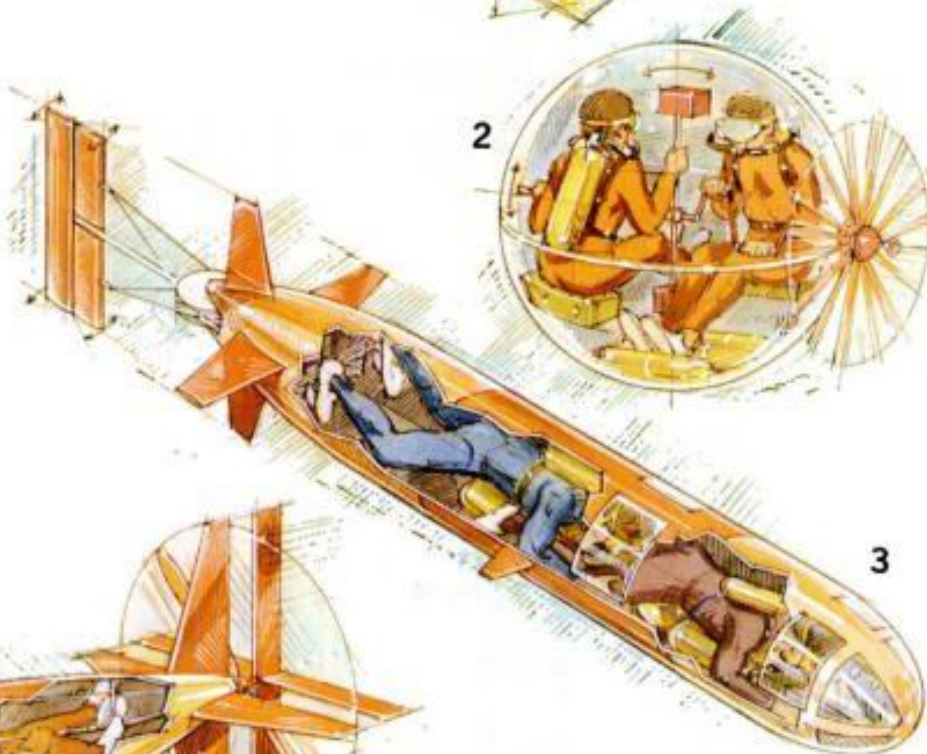
Push a button, and the remote-controlled Letter Sledder extends into your car, so you can easily retrieve your mail. Two models are sold: electrically wired (\$200) or solar powered (\$250). They fit any mailbox. Todd Powers Associates, 825 Harper Dr., Algonquin, Ill. 60102.



Six of the 20 entries in the human-powered submarine race this month include the U.S. Naval Academy's *SQUID*, an epoxy, fiberglass, and Airex foam design. Earlier this year it won the American Society of Mechanical Engineers ocean-division design competition. The 60-inch transparent plastic sphere from Innerspace Corp. has a large front surface and uses only arm power, limiting its speed to about two knots. The *Gossamer Albacore* features an unusual fish-tail propulsion system. A team from the Lockheed Advanced Marine Systems division created a pistonlike mechanism to power the cable-and-pulley actuated three-piece fin. A large variable-pitch propeller and killer-whale shape highlights the 13-foot-long *Da Vinci* from San Diego's Will Forman. Both arms and legs will be used in an attempt to reach five knots (nearly six mph). Another entry, *Imagining's Nicole's Nickel* may reach the same speed with a variable-pitch propeller and a coating over half its body of drag-reducing riblet film, which has tiny grooves along its surface. The entry from MIT is based on declassified Navy studies. A new twist to reduce turbulence is a narrow slot around the circumference of MIT's sub that draws off a layer of nearly turbulent water with a pedal-powered pump (see detail).



1



2

3

4

5

6

SUCTION CONDUIT TO PEDAL-POWERED PUMP

TAPE

HULL LAMINATE

NEAR-TURBULENT BOUNDARY LAYER

SUCTION SLOT

NEW LAMINAR-FLOW BOUNDARY LAYER



WEATHER SATELLITE

ILLUSTRATION BY DEAN ELLIS

the tornado had passed. "Here we were," he remembers, "sitting outdoors in the pouring rain in the midst of what a few moments before had been our home."

Lucky to be alive, the Hogans are survivors of a strong F3 tornado (see box, Measuring Tornadoes). Edmond, a suburb of Oklahoma City, lies in the Midwest corridor from Texas to Wisconsin, where tornadoes are most prevalent. The town is only a few miles from Norman, where researchers from the National Severe Storms Laboratory (NSSL), the University of Oklahoma, and the National Weather Service are working to improve the forecasts and warnings of severe storms.

In recent years, researchers using pursuit vans that carry portable radar equipment and sensor-equipped balloons have been able to intercept storms in the field, measuring variables they couldn't study before—like the speed of winds that are rotating inside a tornado. And in the laboratory, researchers studying simulated tornadoes are testing new ways to calculate the strength of the swirling winds. These data, when combined with information gathered by meteorologists who are monitoring storms from weather stations, should give researchers a detailed model of tornado behavior, which will help them predict the arrival of violent storms—hours in advance, perhaps. To learn how the new tools are being used, I visited the research centers in the heart of tornado country, and even went along on a tornado chase.

Born in the U.S.A.

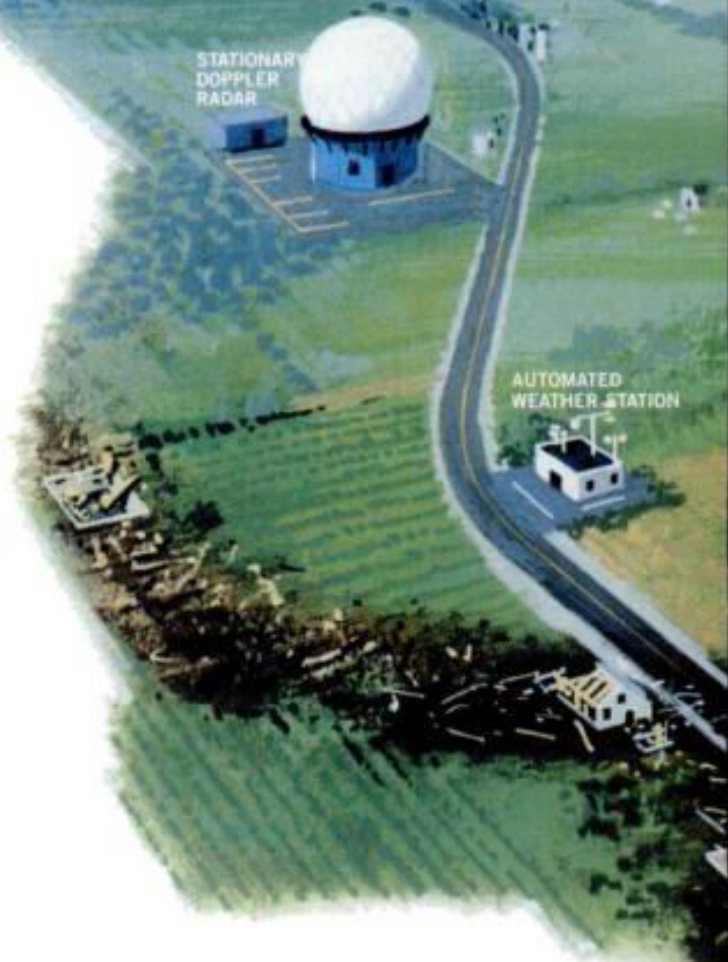
Tornadoes can strike anywhere in the United States, which has more tornadoes than any other country. (A tornado is any rapidly rotating column of air that touches the ground. In the air, it's called a funnel cloud.) Tornadoes are most apt to occur during the late afternoon and evening hours in the spring and fall, when the air is least stable.

"First there has to be a favorable area for thunderstorms to form—an unstable air mass in which the wind direction turns with height," says NSSL meteorologist Dr. Edward Brandes. "If the air is then lifted by a passing cold front or rises because of daytime heating, a mesocyclone—a

Continued

INSIDE A TORNADO

Tornadoes almost always begin with mesocyclones, severe thunderstorms containing rotating updrafts of warm air. When these updrafts occur in the relatively rain-free right rear portion of a storm, they can draw in air from cool downdrafts trailing the storm and form funnel clouds. Those that touch down become tornadoes. Sometimes suction vortices, fierce miniature twisters 30 to 100 ft. across, swirl around the main funnel. Scientists study tornadoes with satellites, stationary and mobile laboratories containing a variety of instruments, radiosondes, and Doppler radar.





RADIOSONDE
(CARRIED BY
WEATHER
BALLOON)

INTRACLOUD LIGHTNING FLASHES

DIRECTION OF STORM MOVEMENT

MESOCYCLONE

EMBRYO
CONDENSATION
FUNNEL

SINKING COLD AIR
(INTENSE DOWNDRAFTS)

SUCTION
VORTICES

STRONG ROTATING UPDRAFTS
(WARMER AIR)

RAIN AND LARGE HAIL SHIELD

PORTABLE
DOPPLER
RADAR

PROJECTILES

MOBILE
LABORATORY

DEBRIS





Don't



Two novel boat hulls that reduce the rock and roll of rough seas are being fitted to luxury pleasure craft. The catamaranlike hulls gain stability differently: One has submerged pontoons that cruise smoothly below waves; the other has a cushion of pressurized air that rides above the turbulence.

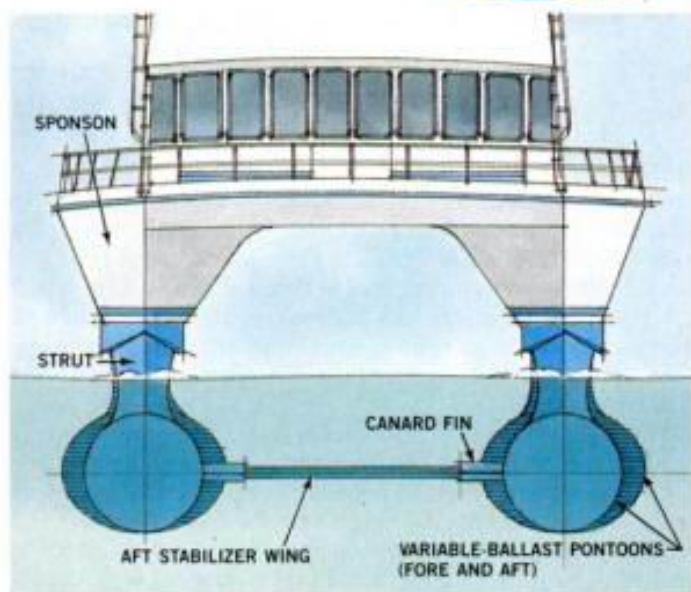
By **BILL McKEOWN**

Illustrations by Barry Ross

A pair of innovative marine hull designs is joining pills, medicated patches, and brewed potions to prevent that ancient curse of the unruly seas—motion sickness. Though these high-stability hull configurations have been used previously on large naval and commercial vessels, only recently have they been adapted to high-priced pleasure boats.

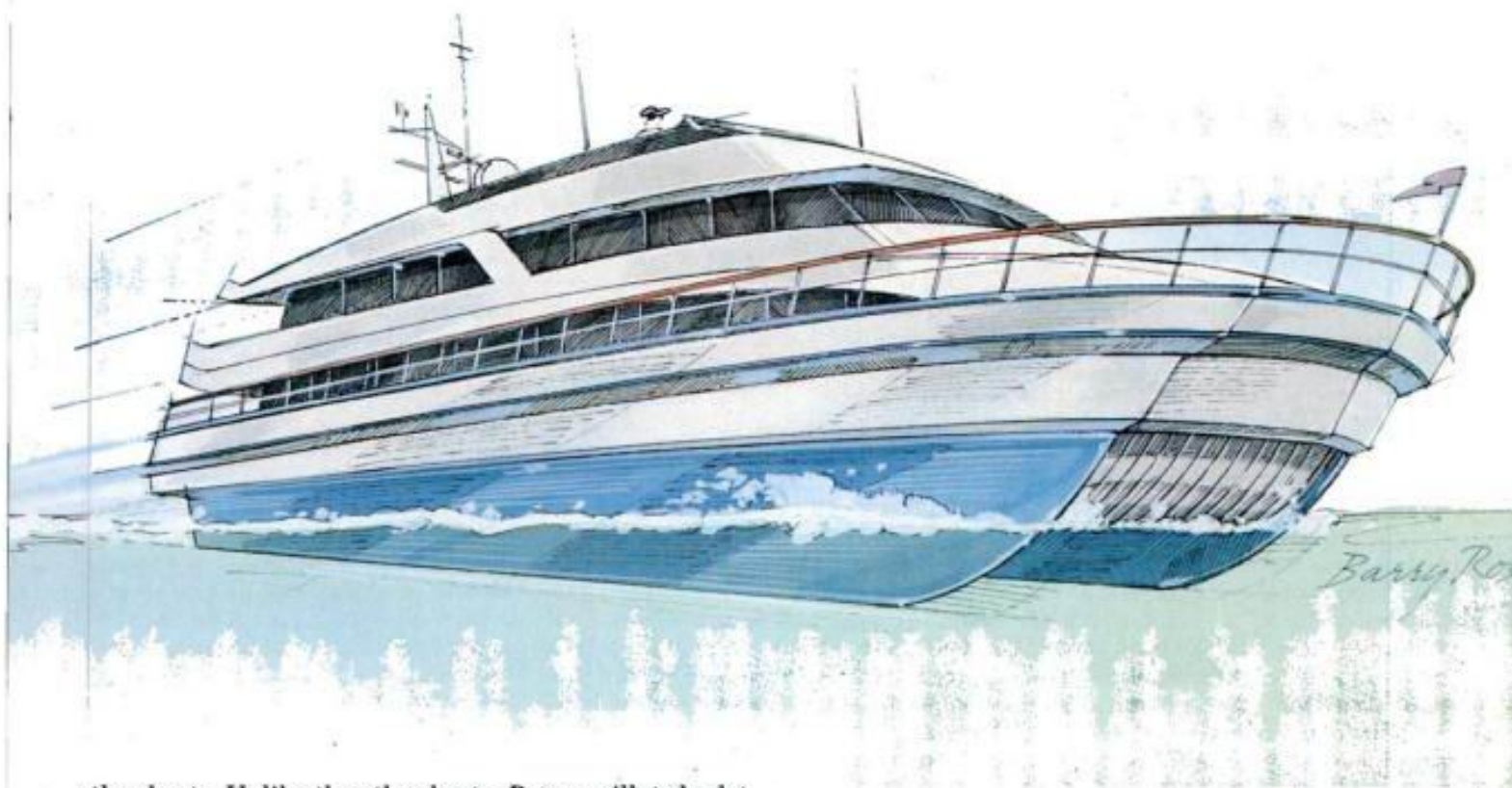
Key to both of these novel hull shapes is that they avoid riding the turbulent water surface where waves make conventional single-hulled vessels pitch, roll, and heave. Instead, they cruise where the going's much smoother: either above or below the ever-moving waterline.

During the 1986 America's Cup yacht race in Australia, the *Betsy*, a tender for the winning *Stars and Stripes* sailboat, cruised the rumpled waters off Perth along with many



Chubasco, the 72-foot Swath Ocean Systems yacht (pictured above and at the top) rides rough seas with the sea-keeping ability of a much larger single-hull boat design. Its high resistance to pitching, rolling, and heaving results from a special undersurface configuration called a small water-plane area twin hull (Swath). Most of the Swath yacht's flotation volume resides in the submerged pontoons that cruise the relatively calm water that lies below turbulent surface waves. In addition, horizontal fins and wings positioned between the struts counteract up-and-down motion.

rock the boat!



other boats. Unlike the other boats, *Betsy* oscillated a lot less in the waves. Soon landlubber cameramen with queasy stomachs began to favor it as the preferred platform for filming the race. "It was like reporting from an aircraft carrier," one ESPN sportscaster remembers. *Betsy* was signed on once more for last year's A-Cup event.

Betsy's secret lies below the water surface. The boat has a special underwater shape called a small waterplane area twin hull, or Swath, to keep her on an even keel.

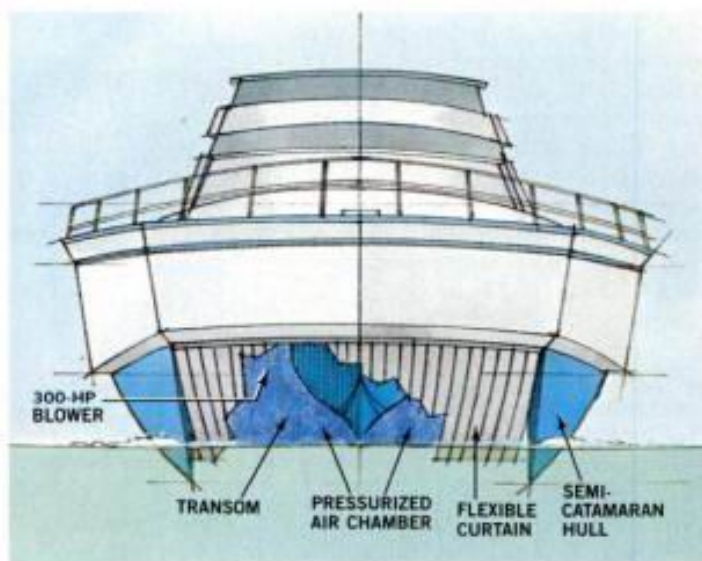
Now sharing this Swath shape is the latest development for smoother pleasure boating, a 72-foot aluminum luxury yacht called *Chubasco*. The multimillion-dollar concept craft, built in San Diego by Swath Ocean Systems, is on sea trials in the Pacific off California.

Below the waves

Looking like a raised-deck catamaran mounted on struts, the *Chubasco* rides with the cabin 10 feet above the water. Unseen 10 feet below the surface waves are bulbous pods at the fore and aft ends of twin cigar-shaped pontoons. These pods act as stabilizers to keep the craft from rolling. They improve the Swath boat's stability because its flotation volume lies in the calmer waters below the surface turbulence.

Horizontal canard fins extending partway into the center tunnel from both forward bulges and a stabilizer wing connecting the aft pods help dampen pitching and rolling as well as allow *Chubasco* to bank into turns. The larger Coke-bottle-shaped bulges at the stern house twin 750-

[Continued on page 102]



A surface-effect ship (SES), such as the 87-foot Cheoy Lee/Air Ride pleasure craft (shown above), provides stability in rough seas by using an air cushion to raise most of the hull above the waves. Unlike a hovercraft, an SES encloses its blower-maintained air cushion within a blind tunnel formed by catamaranlike side hulls, a stern wall, and the water surface. At the bow a flexible curtain closes off the escape of air forward.



The X-31 supermaneuverable fighter will demonstrate the feasibility of "post-stall" flight: that is, controlled flight at high angles of attack—the angle of a wing's chord to the relative wind. This extreme nose-up condition causes conventional airplanes to stall and fall into a tailspin. The tremendous agility made possible by operating in this post-stall flight regime will permit rapid fuselage-pointing and target-acquisition during the course of air-to-air combat—the keys to victory in future dogfights.

To date, the aerodynamics of post-stall flight remain relatively unknown. Flight tests of the X-31 will do much to advance aerodynamicists' understanding of the subject. When a plane climbs into a beyond-stall angle of attack, the airstream over its wings rapidly changes from a fully attached, lift-producing flow to a fully detached, zero-lift flow, explains Capt. Hank Helin, program manager for aerospace science at the Air Force Office of Scientific Research, Washington, D.C. According to Helin, the phenomenon occurs

as follows: In this nose-up attitude, extremely low air pressures on the dorsal wing surface cause a complex system of vortices to form in the viscous boundary layer of air adhering to the wing surface. This vorticity accumulates and then rolls up into large dynamic stall vortices, which convect off aircraft surfaces. Vortex shedding can place large instantaneous loads and moments on the airframe that must be managed. Complex supercomputer simulations now allow aerodynamicists to predict these events with sufficient accuracy so they can design the X-31 to be strong enough to resist the loads. The calculations also permit the plane's computerized-control system to be programmed to accommodate the transient moments so the vortex shedding doesn't produce loss of control.

A thrust-vectoring system (1) will permit the X-31 to retain directional and attitudinal control even when its flight-control surfaces become inoperative due to post-stall



X-31

How they're inventing a radical new way to fly

Victory in dogfights goes to the pilot who jockey's his fighter into position and launches first. As missiles grow smarter, even greater agility will be required. That means pilots will fly at angles of attack that normally cause an airplane to stall and fall into a tail-spin. To explore "post-stall" flight, an experimental aircraft called the X-31 supermaneuverable fighter is being built by the United States and West Germany. It will pioneer this wild way to fly.

By **JIM SCHEFTER**

Illustrations by Mark McCandlish

conditions. The plane's flight controls will use the thrust-vectoring system to power the aircraft through the "rough" spots of post-stall maneuvers by brute force. The thrust-vectoring system consists of three paddles or vanes that can move into the exhaust stream to deflect it to one side or the other. The vanes can deflect up through 10 degrees in both the pitch and yaw orientations.

The X-31's flight control surfaces include a forward canard that can rotate 90 degrees (2), wing-tip elevons (3), and trailing-edge flaperons (4). These subsystems are integrated into the plane's computerized flight controls.

Several off-the-shelf components were used: the engine is the 12,000-pound-thrust General Electric F404 turbine, the same power plant used in the F-18 fighter. The X-31's canopy, ejection seat, and instrument panel also come from the F-18. Landing gear comes from the F-16 fighter. The flight computer is adapted from a Honeywell computer used in the Air Force's High Technology Testbed.

When he spotted two enemy fighters breaking through the haze blanketing the Baltic seacoast, the NATO fighter pilot wasn't surprised. Though his plane was radar equipped, the veteran pilot had never stopped scanning the sky for intruders. Since the alert, "electronic fog" produced by radar jammers on both sides of the German border had wreaked havoc on his plane's radar set. Now at close range his cockpit radar display showed a pair of ominous red blips starting to wheel in his direction.

With a deft movement of the stick, the missile-laden fighter banked left on cranked-delta wings. The pilot keyed

Continued





© 11.88 MARK McCANPLISH

Workers in Las Vegas, are starting to build a 1.3-mile-long elevated rail that will be dotted with four passenger stations and other transit buildings. But this dual-lane track, unlike massive concrete elevated lines still scarring cities, is svelte and high-tech. Climb aboard the sleek two-car trains that will use this line starting in 1992, and you'll notice something unusual. As the train accelerates to 55 mph you won't hear clacking wheels or engine roar. The murmur of passengers and a low hum of air conditioning will be all you'll notice. That's because the 24-seat cars are magnetically levitated—suspended above metal guide rails—and propelled forward by electromagnetic fields from coils built into the tracks.

After nearly three decades of development, magnetic-levitation (maglev) trains are finally becoming practical. The goal for the mid-1990s is to build high-speed lines that will whisk you at 310 mph between cities less than 500 miles apart, bypassing overburdened airports and clogged highways. Slower maglev vehicles will carry passengers from airports into cities or transport commuters. For intercity travel, maglev could beat door-to-door air times because downtown train terminals eliminate airport trips and departure delays.

West Germany appears closer to building high-speed city-to-city maglev lines than its only rival, Japan. But both are pushing maglev projects around the world. The Germans have scheduled a 95-mile Hanover-to-Hamburg route for the mid-1990s and have targeted a 230-mile link from Las Vegas to Los Angeles. A German firm is completing tests on a people-mover system within West Berlin; its American subsidiary is building the Las Vegas people mover. Japan has budgeted two maglev lines at home, and one Japanese firm wants to start a *second* downtown Las Vegas system. Great Britain has had a short-run maglev people mover operating for years at Birmingham's airport [Oct. '84]. While the United States pioneered maglev development ["Maglev: How They're Getting Trams Off The Ground," Dec. '73], significant research was stopped in the mid-1970s. Some maglev proponents and legislators, though, hope to revive U.S. maglev technology and leapfrog Japan and Germany (see box).

Billions for maglev technology

Experts think West Germany now leads Japan in the high-speed maglev race. Three factors have helped put Germany ahead:

Government support. During the 1960s, the German government announced that by the end of the century it wanted a means of transporting passengers and freight at 310 mph between Hamburg and Munich. Research contracts to firms have been generous. So far the leading high-speed intercity system has received about \$833 million in

310-mph flying trains

—in the '90s —in the U.S.

Impatient Las Vegas officials have promoted a high-speed train link to Los Angeles for years. Now the West Germans say they're ready to build a remarkable magnetic-levitation line that can zip passengers between the two cities in only 75 minutes.

**By DAVID SCOTT
and JOHN FREE**

Drawings by Mario Ferro



Transrapid 07, the latest maglev vehicle from a West German consortium, noses from an exhibition hall at a Hamburg show last year. An earlier model set a 256-mph speed record at a 20-mile test track in northern Germany (below). Battery-powered electromagnetic lift/drive magnets are mounted along underslung bogies on both sides of Transrapid vehicles. These magnets are attracted to thick metal plates anchored along the guideway, which levitates the vehicle to within $\frac{1}{2}$ -inch of the plates. The plates, wound with inch-thick cables (right), are also the stationary portion of the linear-induction motor that propels Transrapid 07. Substation current fed to these plate windings produces magnetic fields that interact with fields of the lift/drive magnets. This pulls and pushes vehicles along the guideway. Guidance magnets keep vehicles separated from guideway edges.

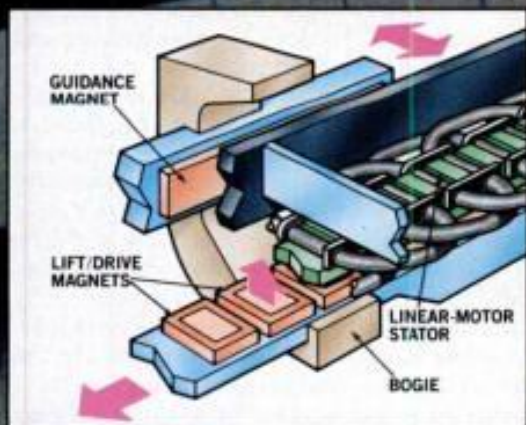


government funds. But political opposition is growing as the date to spend nearly \$2 billion on the first maglev link from Hanover to Hamburg approaches. In comparison, Japanese researchers have received less-generous funding and stumbled on bureaucratic delays that have hindered development.

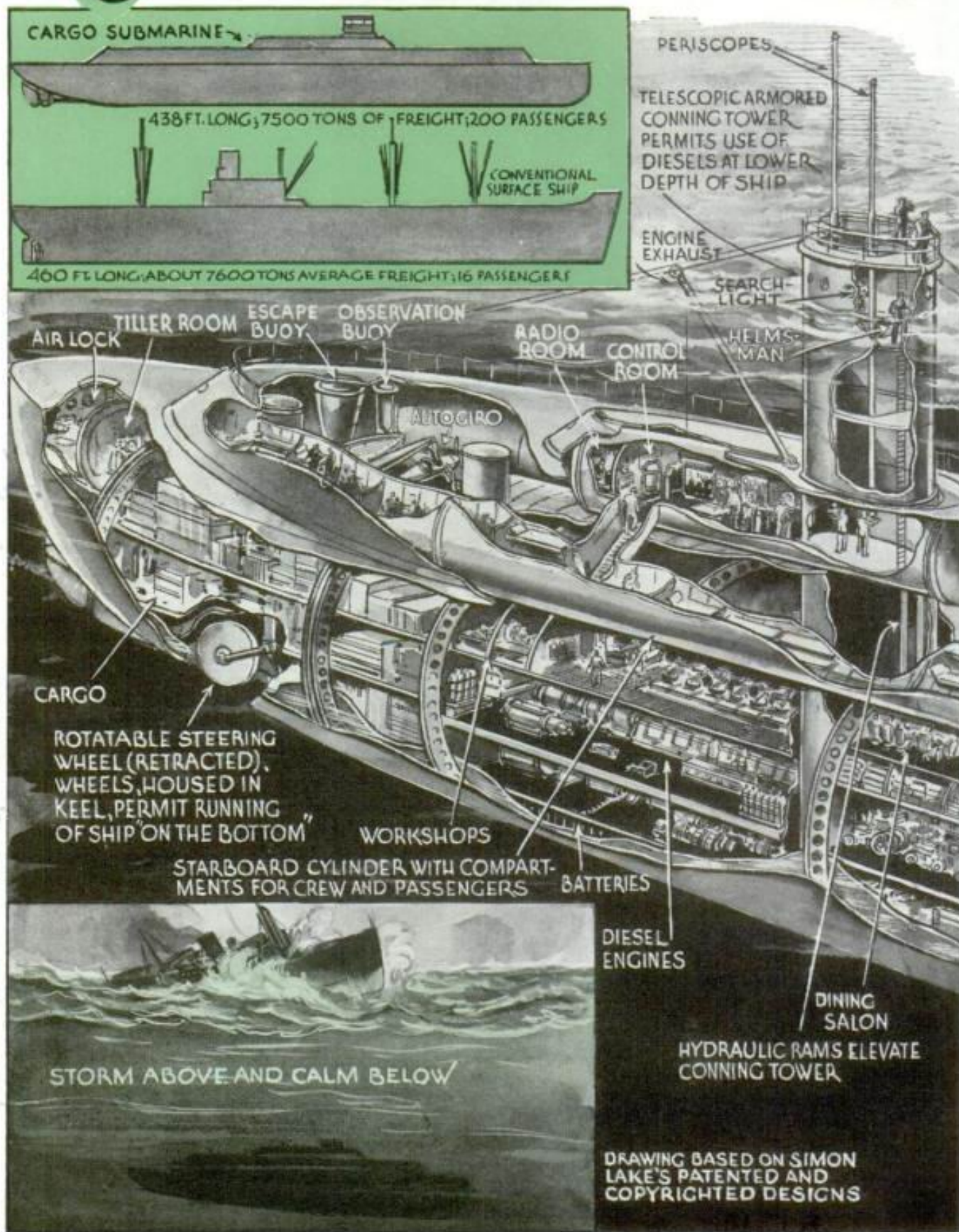
Technology. Germany made an early decision in the high-speed-maglev race to concentrate on vehicles that use conventional electromagnets. These magnets are attracted to metal rails above them, lifting maglev cars a fraction of an inch above guideways (diagram). This attractive-maglev

technology is now used for Germany's leading candidate for intercity maglev transportation, Transrapid International's TR07. For its intercity maglev vehicle Japan focused on technology that exploits repulsion between like magnetic poles. This repulsive maglev depends on the powerful magnetic fields produced by superconducting magnets. Special wire for these electromagnets loses its resis-

Continued

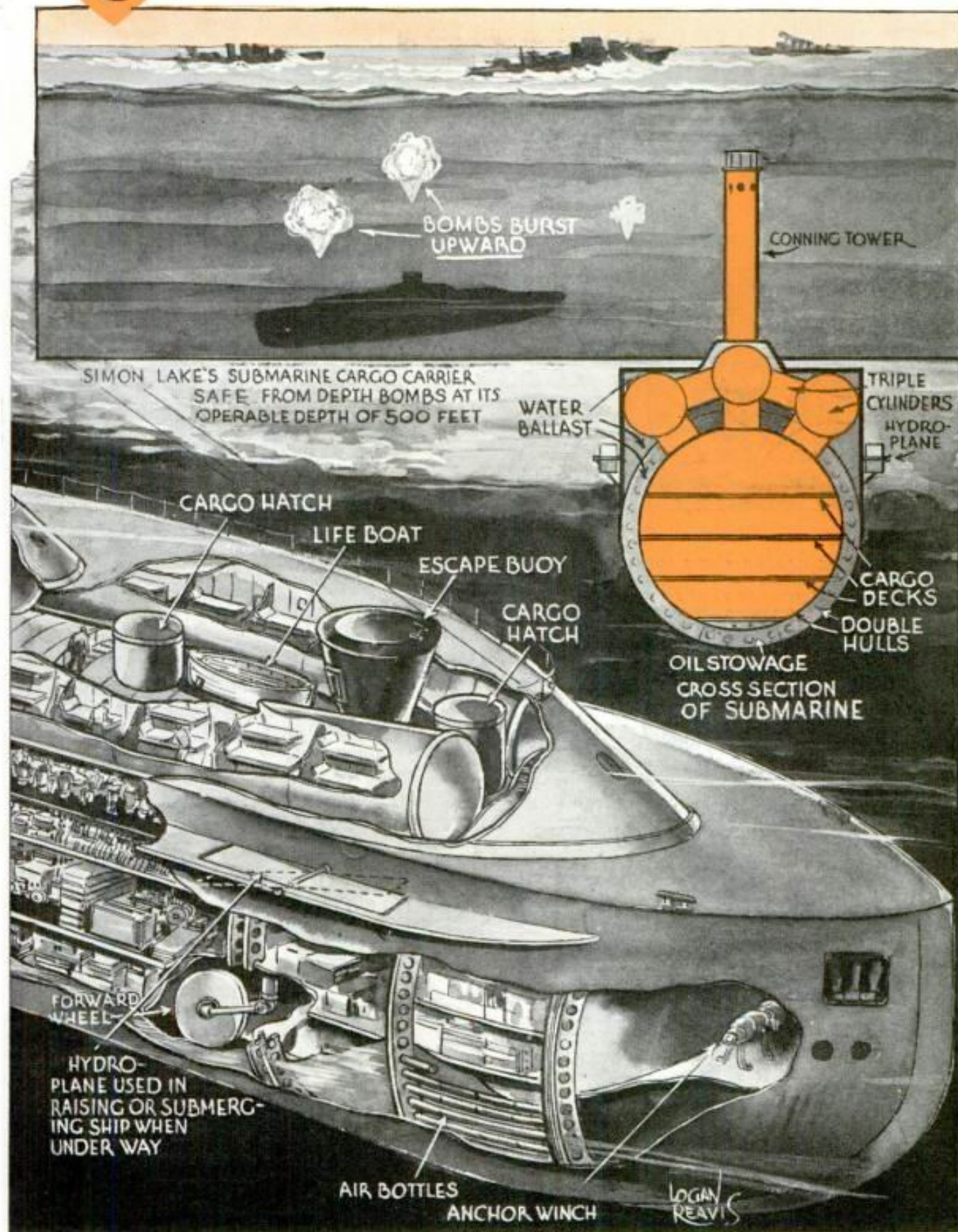


UNDER WATER

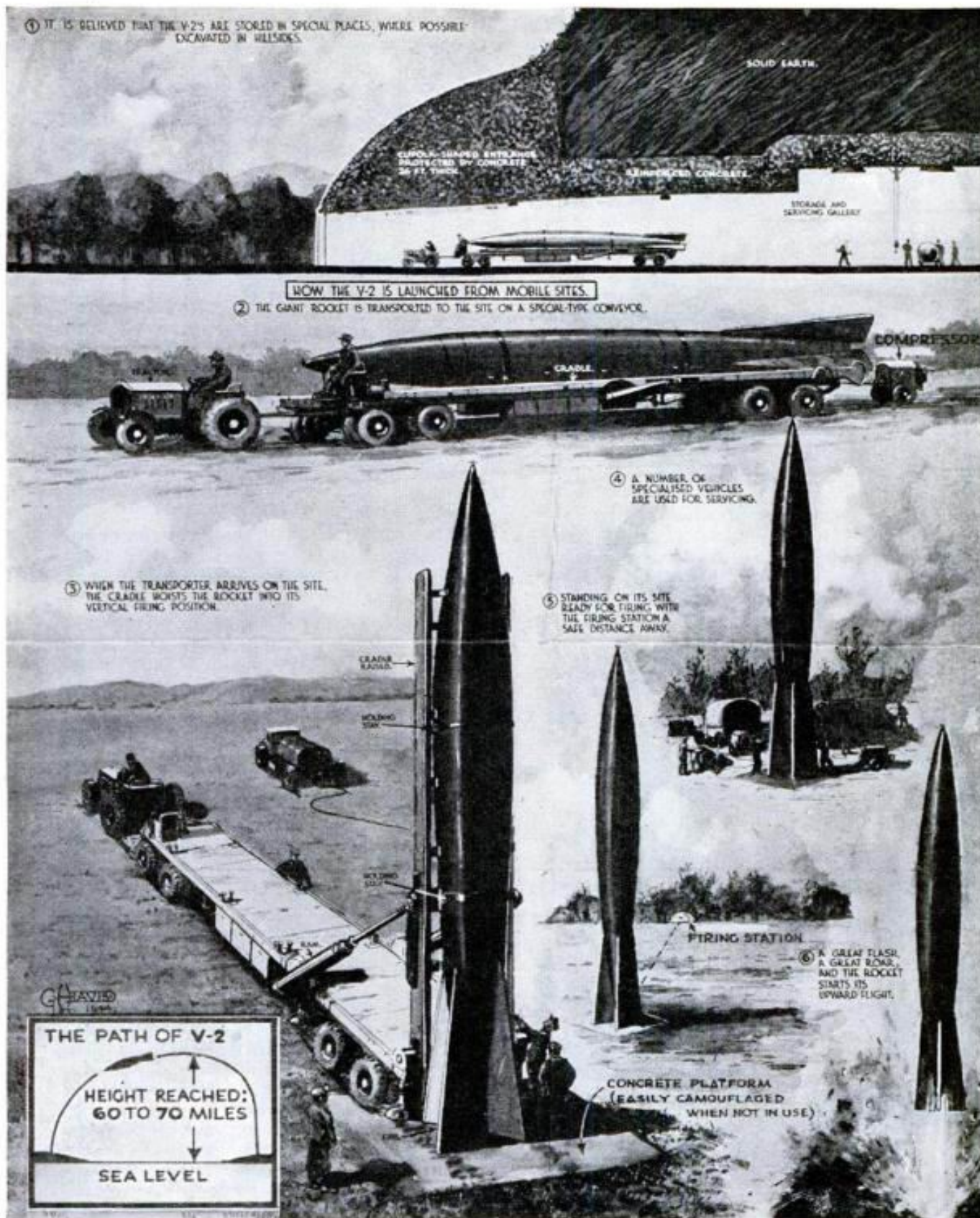


Cargo-carrying submarines, of the type shown in these drawings based on Simon Lake's copyrighted designs, may solve war-time shipping problems and may permit ocean freight to reach ports closed to surface vessels by ice. Among its features is an observation buoy in which a member of the crew could rise to the surface and look around

CARGO CARRIER



Simon Lake's designs call for all-welded construction, special life-saving features, strength to permit submerging to 500-foot depths, a surface speed of twelve knots and a submerged speed of ten, space for 7,500 tons of freight and 200 passengers in an underwater craft 438 feet long and retractable wheels which permit running on ocean floor



HOW NAZIS LAUNCH V-2 ROCKET

USING an RAF reconnaissance photo made over Peenemunde, Germany, as a guide, artist G. H. Davis drew these sketches for *The Illustrated London News* to show how the Nazis launch the terrifying V-2 rocket.

The bombs are stored, it is believed, in huge caves dug in hillsides and heavily reinforced. They are hauled to concrete firing platforms on big trailers and raised to an almost vertical position before being discharged.

First Photos of Peru's Great Wall

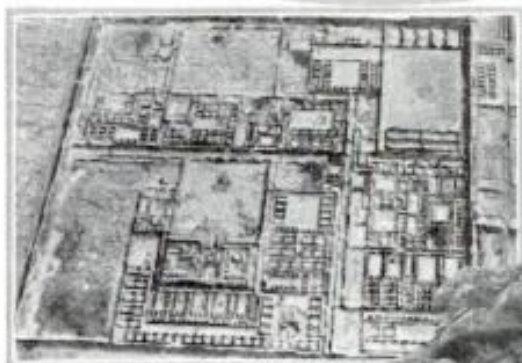


At right, air view of Peru's Great Wall showing how it passes into the heart of the Andes. Above, explorers' plane after smashing against stone wall. At center are leaders of the expedition, George Johnson, elbow on engine, and at his left young Robert Shippee. Below, map of route followed by the two explorers

© Aerial Explorations, Inc.



At left, an air photo of the ancient palace city, Chan-Chan, which was built long before the Incas arrived



FIRST photographs of the amazing "Great Wall of Peru," discovered not long ago by the Shippee-Johnson Expedition in South America, dispel all doubts that this world's wonder actually exists.

By foot and airplane, the two youthful American explorers traced its course from its beginning, near the seacoast town of Chimbote, for forty miles through the Andes until it disappeared in a mass of mountain peaks and ridges. Made of stones cemented with adobe, the barricade rises at some points thirty feet high. It is believed to have been erected at the dawn of the Christian era by the Chimus in a vain attempt to protect their highly cultured civilization. Discovery of the wall, resembling China's famous rampart, was the climax of a trip in which the explorers came unscathed through an airplane wreck and a revolution.



Robert Shippee, twenty-year-old discoverer, inspects the Great Wall which in places rises some thirty feet high

Big Electric Plant Run by Wind



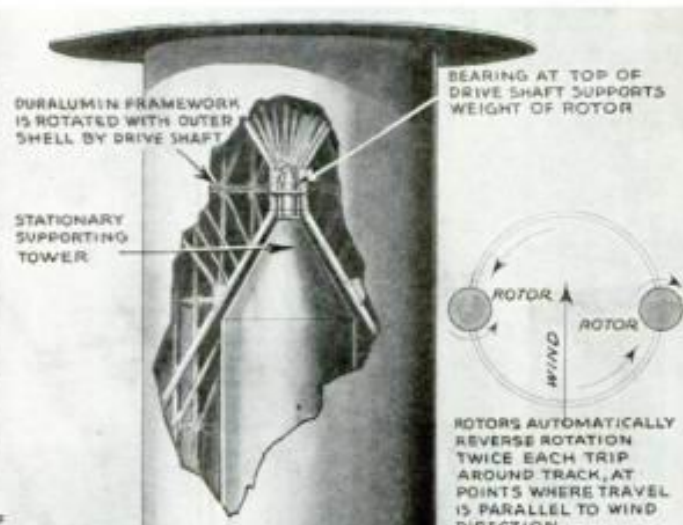
THE IDEA OF HARNESSING THE WIND WITH ROTORS WAS APPLIED TO A VESSEL BY ANTON FLETTNER. THIS SHIP SUCCESSFULLY CROSSED THE ATLANTIC IN 1926



PHOTOGRAPH OF A MADARAS ROTOR MODEL IN A WIND TUNNEL. AIR CURRENTS, FROM LEFT, ARE SPEEDED AT TOP AND IMPEDED AT BOTTOM, AS SMOKE JETS SHOW, CAUSING ROTOR TO MOVE TOWARD PARTIAL VACUUM ABOVE



ANOTHER APPLICATION OF THE ROTOR, THE GERMAN INVENTOR, FLETTNER, DESIGNED THIS ROTOR WINDMILL TO GENERATE ELECTRICITY



DURALUMIN FRAMEWORK IS ROTATED WITH OUTER SHELL BY DRIVE SHAFT

STATIONARY SUPPORTING TOWER

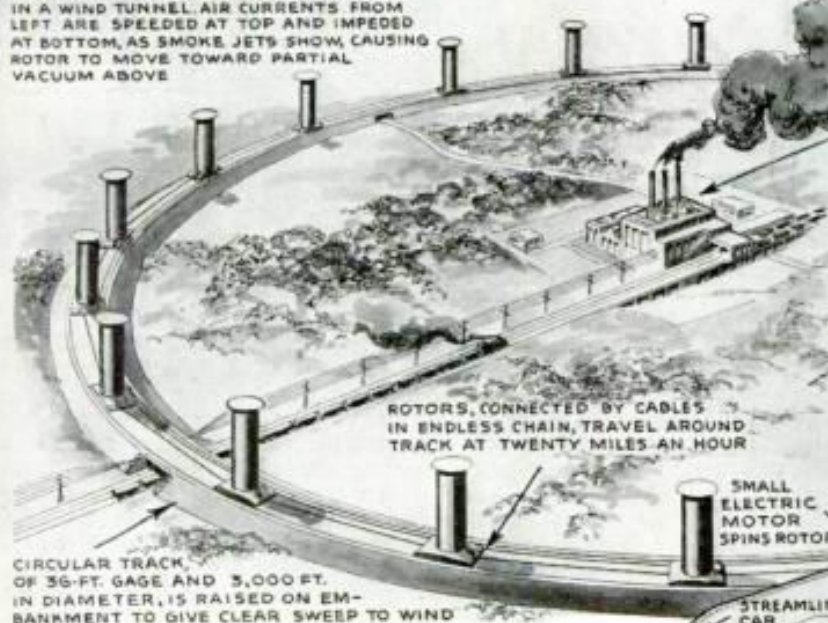
BEARING AT TOP OF DRIVE SHAFT SUPPORTS WEIGHT OF ROTOR



ROTORS AUTOMATICALLY REVERSE ROTATION TWICE EACH TRIP AROUND TRACK, AT POINTS WHERE TRAVEL IS PARALLEL TO WIND DIRECTION

SPINNING ROTOR OF ALUMINUM ACTS AS SAIL TO PROPEL CAR

EACH ROTOR IS 90 FT. HIGH AND 22 FT. IN DIAMETER



CIRCULAR TRACK OF 36-FT. GAGE AND 5,000 FT. IN DIAMETER, IS RAISED ON EMBANKMENT TO GIVE CLEAR SWEEP TO WIND

ROTORS, CONNECTED BY CABLES IN ENDLESS CHAIN, TRAVEL AROUND TRACK AT TWENTY MILES AN HOUR

SMALL ELECTRIC MOTOR SPINS ROTOR

POWER HOUSE STEAM PLANT SUPPLEMENTS POWER FROM ROTOR ON DAYS WHEN WIND IS WEAK



BEARING RING

ROLLER BEARINGS TAKE SIDE THRUST OF ROTOR

DRIVE SHAFT

REVERSE GEAR

GENERATOR DRIVE GEAR

GENERATOR PRODUCES POWER WHEN CAR TRAVELS AROUND TRACK

THIRD RAIL COLLECTS CURRENT FROM ALL ROTOR CARS AND CONDUCTS IT TO POWER HOUSE

CONTACT FEEDS POWER FROM GENERATOR TO THIRD RAIL

POWER FROM THE AIR

Drawing shows in detail how gigantic power plant will be operated by air currents which will drive the big cylinders around a circular track to propel streamlined flatcars and turn dynamos to generate electricity

AN AMAZING "merry-go-round" power plant to harness the wind for electrical energy is soon to be built, somewhere in the East, if final tests now under way prove successful. Twenty spinning cylinders will rumble around a track 3,000 feet in diameter in an endless train. They will propel flatcars and turn dynamos geared to the axles.

Fantastic as the project sounds, prominent engineers have indorsed it, and six of the most important power companies in the United States have financed the build-

ing of the first \$100,000 experimental cylinder. Now rising at West Burlington, N. J., this seven-story-high shaft of aluminum recalls the cylinders that propelled Germany's famous "rotor ship" of a few years ago. Like them, it operates on the principle of the so-called "Magnus effect"—that a cylinder spun in the wind tends to move at right angles to the breeze.

The inventor, Julius D. Madaras, a Hungarian engineer living in Detroit, revealed the details of the proposed power station in an interview with POPULAR

SCIENCE MONTHLY. Electricity from dynamos on the rotor cars, moving at a fixed speed under automatic control, will be collected by a third rail and conducted to a substation for distribution to the surrounding country. Since the rotors must be spun artificially, a small electric motor keeps each one turning, but it uses only a small proportion of the power generated.

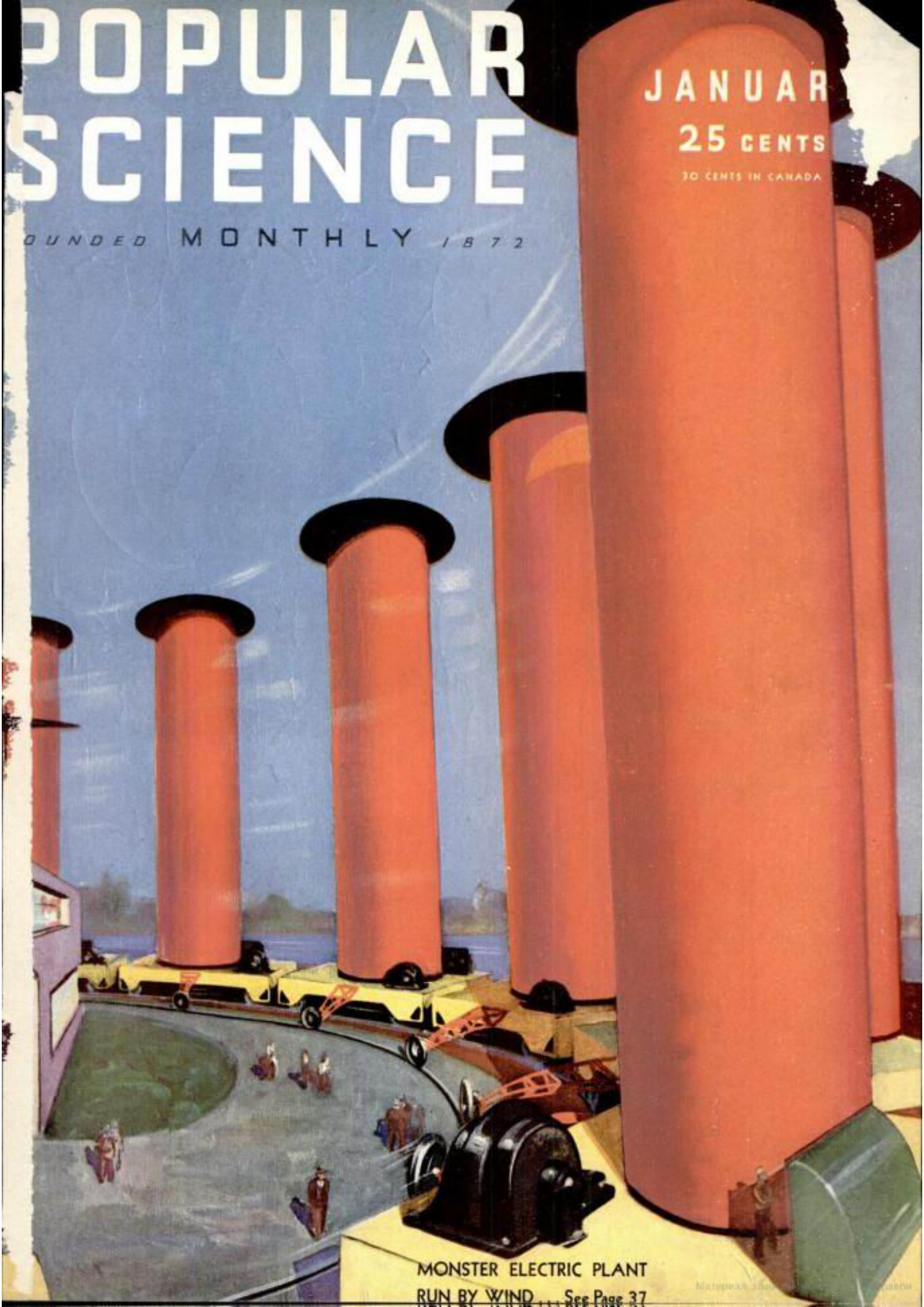
With a twenty-eight-mile wind blowing, Madaras estimates, the completed plant would supply enough electricity for a city of 150,000 inhabitants.

POPULAR SCIENCE

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MONSTER ELECTRIC PLANT

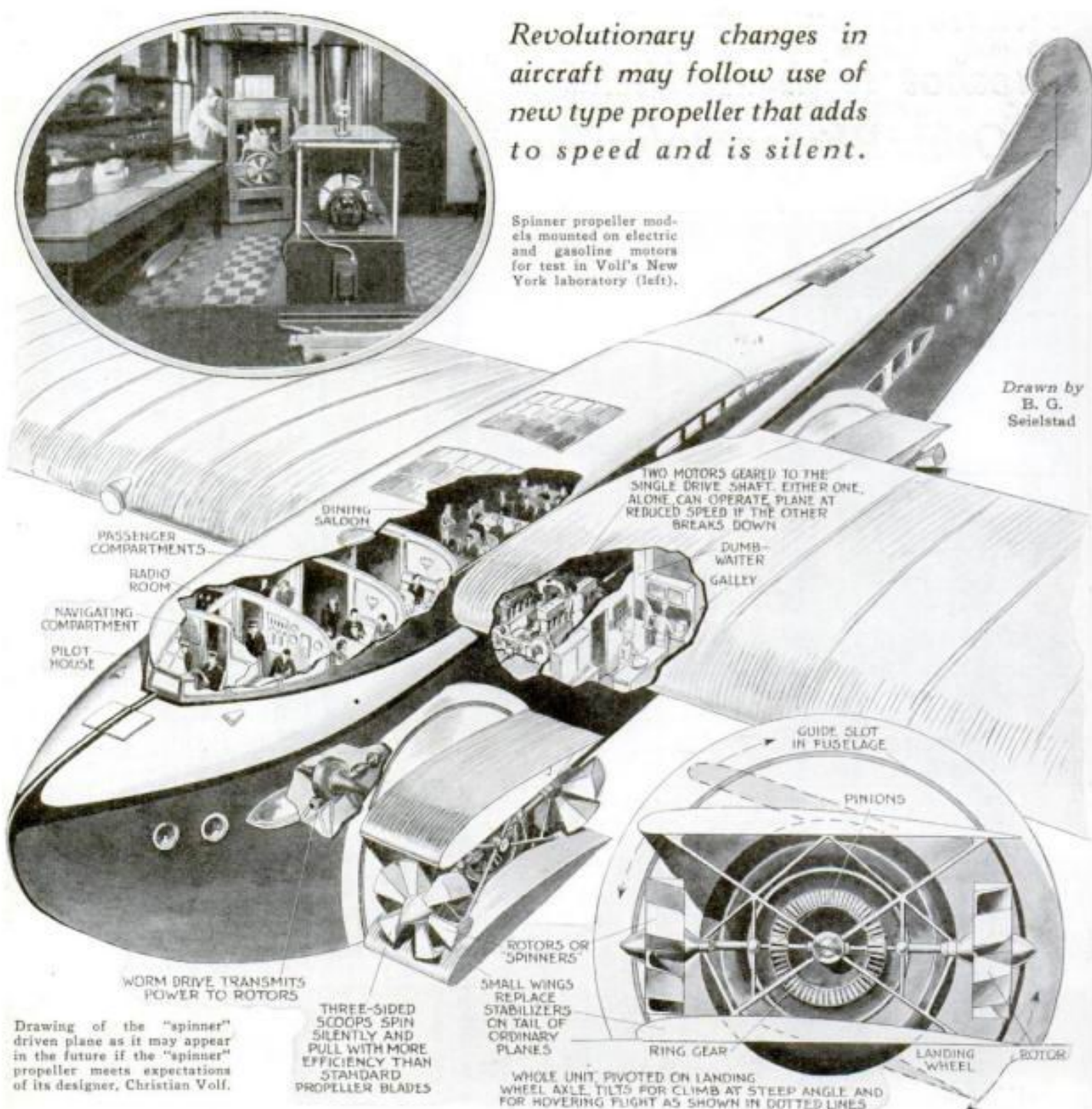
RUN BY WIND... See Page 37

Spinner Plane Bids for Air Supremacy

Revolutionary changes in aircraft may follow use of new type propeller that adds to speed and is silent.

Spinner propeller models mounted on electric and gasoline motors for test in Volf's New York laboratory (left).

Drawn by
B. G.
Seielstad



Drawing of the "spinner" driven plane as it may appear in the future if the "spinner" propeller meets expectations of its designer, Christian Volf.

A DESIGN for a siren gave Christian A. Volf, Danish-born acoustical engineer, an idea that may lead to such a new departure in aviation as the aerial leviathan on this page.

One day in his New York City laboratory, Volf was struck with the likeness between the spinning rotor that makes a siren's whine and an airplane's whirling propeller. The qualities that make a good siren, he observed, make a bad propeller for one reason alone—noise. Aviation engineers would like to quiet the propellers of airplanes, for they make even more sound than the motor.

Many aviation experts have sought better propellers, but Volf started from an entirely new angle—that of the acoustical expert. A "silent siren" could easily be

built. Proceeding on this idea, he set out to design a noiseless airplane propeller. Instead of slashing at air, it would slip through it. The result of his work is a novel "spinner" or rotor rimmed with three-bladed scoops.

Volf set up his new propeller and a standard marine propeller in a tank of goldfish. The fish were struck and killed by the revolving blades of the standard propeller. But they were sucked through the blades of Volf's rotor, following the natural course of the water, uninjured.

Whirling the new rotor in air confirmed that it was silent. But it showed a fact far more interesting. Its tractive force upon models was amazing, according to Volf. The combination of suction and pressure that it produced seemed to give

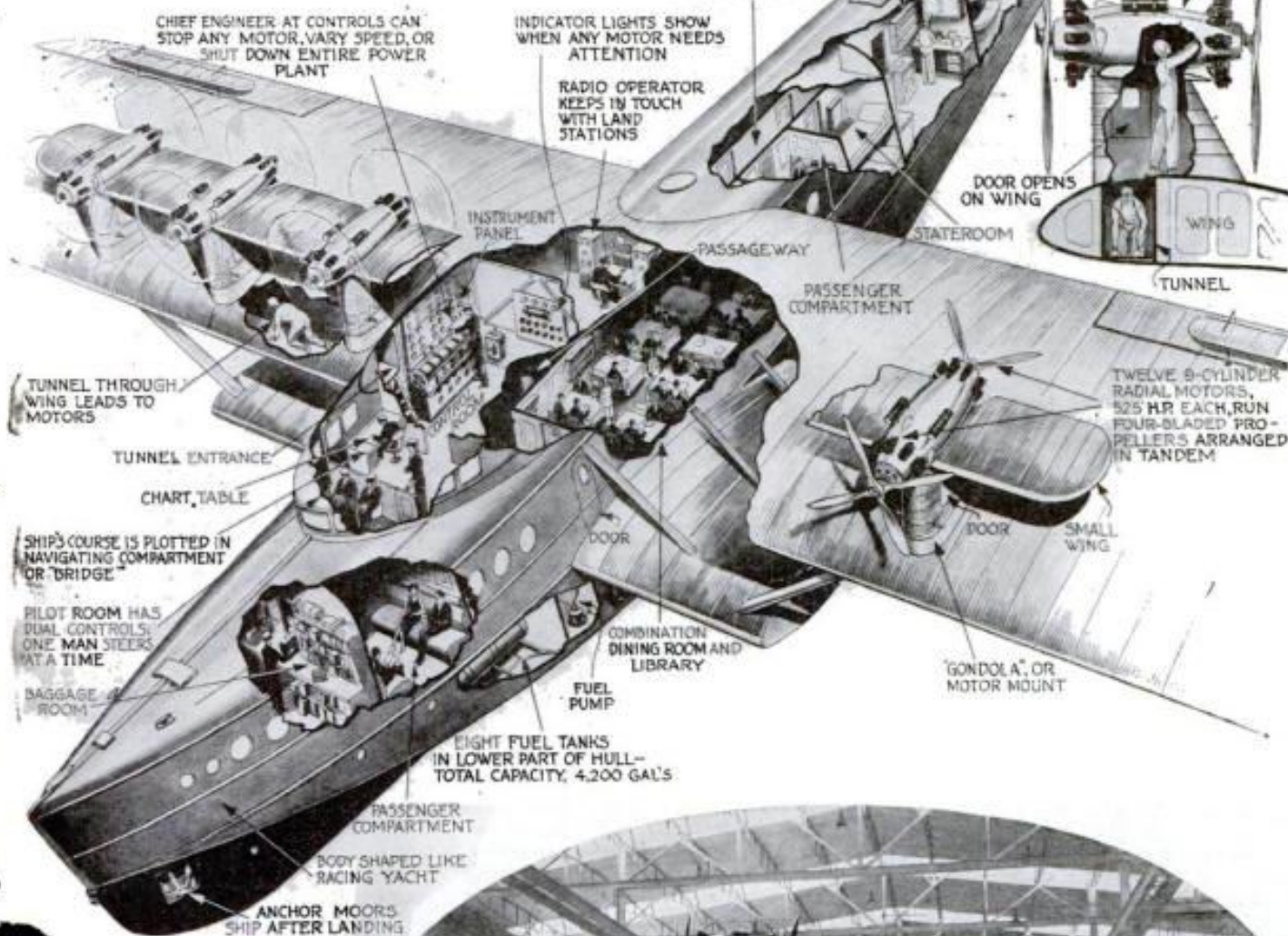
an efficiency far surpassing that of standard propellers.

Out of this idea was born the revolutionary airplane that Volf now proposes. Enormous and silent, it would be driven by eight of the odd spinners, or rotors, that Volf has invented, arranged in pairs. Each pair would have a vane above and below to direct the air through the blades. The whole assembly of rotors and vanes would be revolved at will by the pilot to tilt the ship up or down.

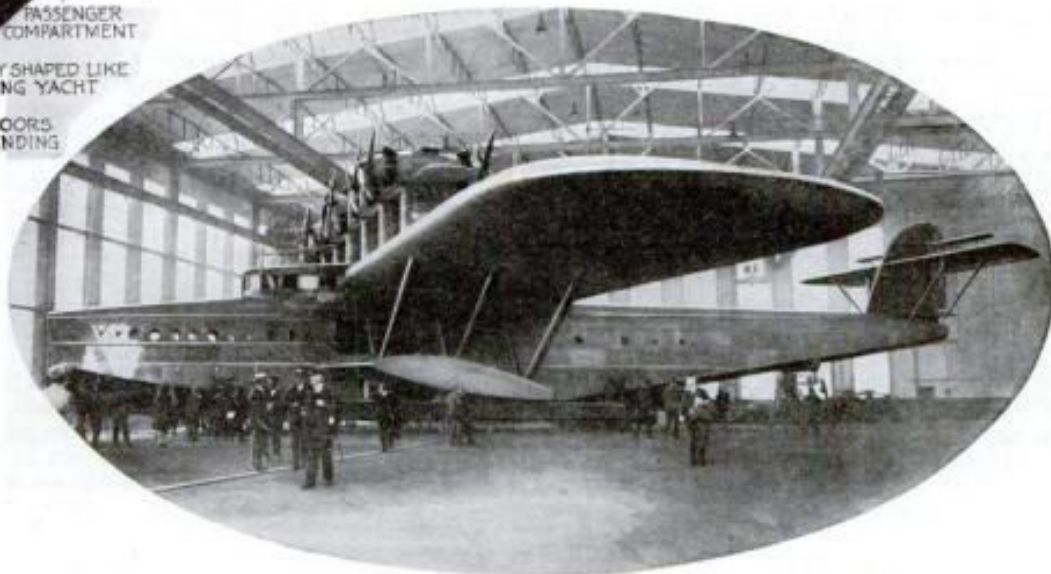
Theoretically, Volf declares, the spinners should be so much more efficient than ordinary propellers that they could support an airplane with practically no wing at all. He proposes first to build a wingless craft, and then add as much wing as turns out to be necessary for flight.

The Mightiest Airplane That Ever Flew

BENEATH the 157-foot wingspread of the biggest airplane ever built—the giant “flying yacht” just completed by Dr. Claude Dornier in Germany—could be hidden a pair of Uncle Sam’s greatest bombers. Construction of the new German monster, pictured on this page, required more than two years, and was one of the greatest engineering feats in aviation history. In her first trial flight with twenty-five persons aboard, the plane rose from Lake Constance, Switzerland, easily lifting her fifty-five-ton loaded weight after a run of only twenty-eight seconds, and flew at 131 miles an hour. She is designed to carry 100 passengers on short cruises, besides a crew of sixteen.

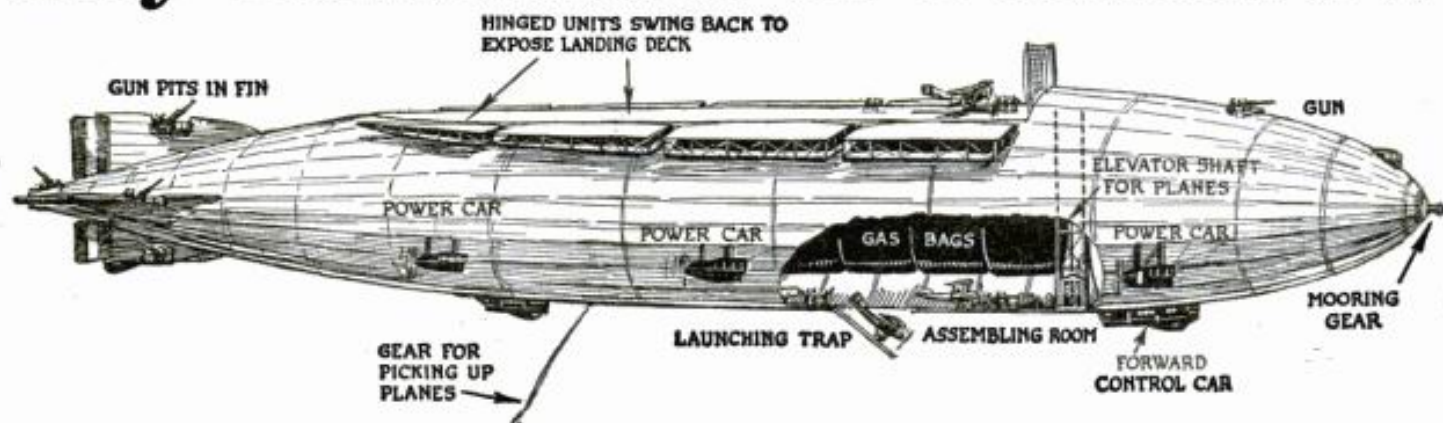


Built with the lines of a racing yacht. This drawing is broken away to show the interior with its spacious accommodations. Three decks are provided for the control rooms, passenger accommodations, and fuel and storage compartments. This is the first airplane to have a captain and a chief engineer. As on an ocean liner, the pilot's only job is to steer. The small drawing at the upper right shows how the engines may be repaired in flight. Mechanics crawl through wing tunnels to replace small parts.



The new Dornier plane, 230 feet long and 33 feet high, just before launching at Lake Constance. It weighs almost four times as much as the largest plane previously built, yet can carry as much weight again in useful load.

Sky Leviathans of Tomorrow



Above is a diagrammatic representation of a possible monster plane-carrying airship of the future. In the accompanying article Rear-Admiral Moffett predicts airships more than

900 feet long. Notice how hinged cover units are swung back to expose a spacious landing deck for airplanes. Alighting, the planes would be lowered into the body of the ship

By Rear-Admiral William A. Moffett

Chief of the Bureau of Aeronautics, United States Navy

SHIRPS of the sea have built empires, altered the destinies of nations, and exerted a profound influence on history through uncounted centuries. With the dawn of the twentieth century, ships of the air have come as a new challenger of time and space, and their influence upon the trend of world events is today one of the most potent factors in world progress and development.

Yesterday we crossed an ocean, today a continent; tomorrow we circle the globe. New routes for commerce open up by way of the polar air routes. London and Tokio are drawn together as by magic, and man, creeping on the earth, looks to the sky and reads there the story of a new era.

It requires no great tax on the imagination to picture some of the developments of air transportation which we may expect to see even in our brief span.

Larger Dirigibles to Be Built

The Navy has built at Lakehurst, N. J., the first rigid airship ever constructed in the United States—the ZR-1. It has been called a giant ship of the air—over 2,000,000 cubic feet of gas will be required to inflate it. It is as large as ocean-going steamers. It can carry a useful load of 35,000 pounds, exclusive of crew and supplies, and withal is mediocre in size and inferior in performance to similar ships that may be expected to follow.

Consider a ship of 5,000,000 cubic feet. Such ships now are being planned abroad. They would equal the size of the *Leviathan*, with a length of 900 feet and more and a diameter greater than the beam of that great vessel. They will carry a weight in fuel and other useful loading of more than 60 tons and could cruise halfway around the earth without a stop. Airplanes could be carried on them as are lifeboats on ocean-going vessels. These planes could land on a deck on top of the airship and be launched from it, carrying passengers for wayside destinations. They could be designed to carry a regiment of troops, and a fleet of them could transport an army to the ends of the earth, in time that could be reckoned in hours.

Imagination—but not too much of it.

Airplanes already have been carried by airships, launched from them, picked up by

them. Polar air routes for short cuts by air commerce are considered the most logical development of dependable aeronautics. This assertion we have from such practical men of science as the noted explorer, Vilhjalmur Stefansson. And England will weld together her empire overseas with giant airships, capable of traveling 10,000 miles and equipped with passenger accommodations comparable to those of the finest transatlantic steamships.

In the light of what has been done by airships operating with airplanes, this development rivals in interest anything that has gone before in aeronautics. The future airship, developed for naval use, will carry a sting that will make it one of the most formidable contenders for supremacy of the air, sea, and earth that has ever been conceived. Allowing 60 tons of useful load to our air giant, we may set aside one half of this for fuel, which will leave 30 tons for planes, landing gear, guns, ammunition, and bombs. Superior types of fighting planes now in service use weigh less than a ton each. Other types of planes have been developed which weigh less than 1000 pounds.

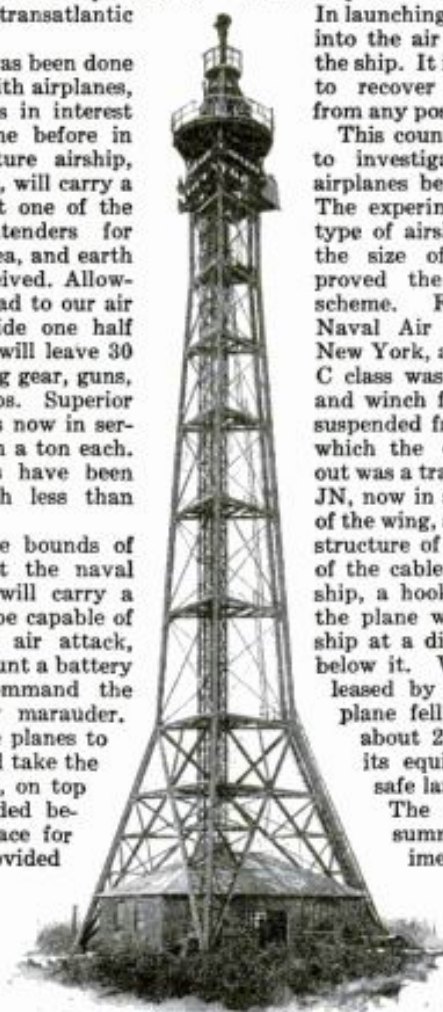
It is well within the bounds of reason to predict that the naval airship of the future will carry a dozen planes that will be capable of defending her against air attack, and in addition will mount a battery of guns that will command the respect of any enemy marauder. Means of returning the planes to the parent airship could take the form of a landing deck, on top of the ship or suspended beneath it. Stowage space for the fighters could be provided in the body of the ship along the keel line. The launching of them is merely a matter of pushing the planes off into space, where they can recover themselves with the ease of a bird thrown into the air.

One of the problems involved is that of keeping the ship's center of gravity below the center line of the envelope. Any extensive structure on the top of the airship involving weight would affect the stability and performance adversely. To offset this obvious difficulty, planes once landed could be quickly disassembled and the fuselage and wings quickly passed through a well in the body of the ship to the stowage space.

In launching, they would be dropped into the air from the under side of the ship. It is no trick among airmen to recover equilibrium in flight from any position.

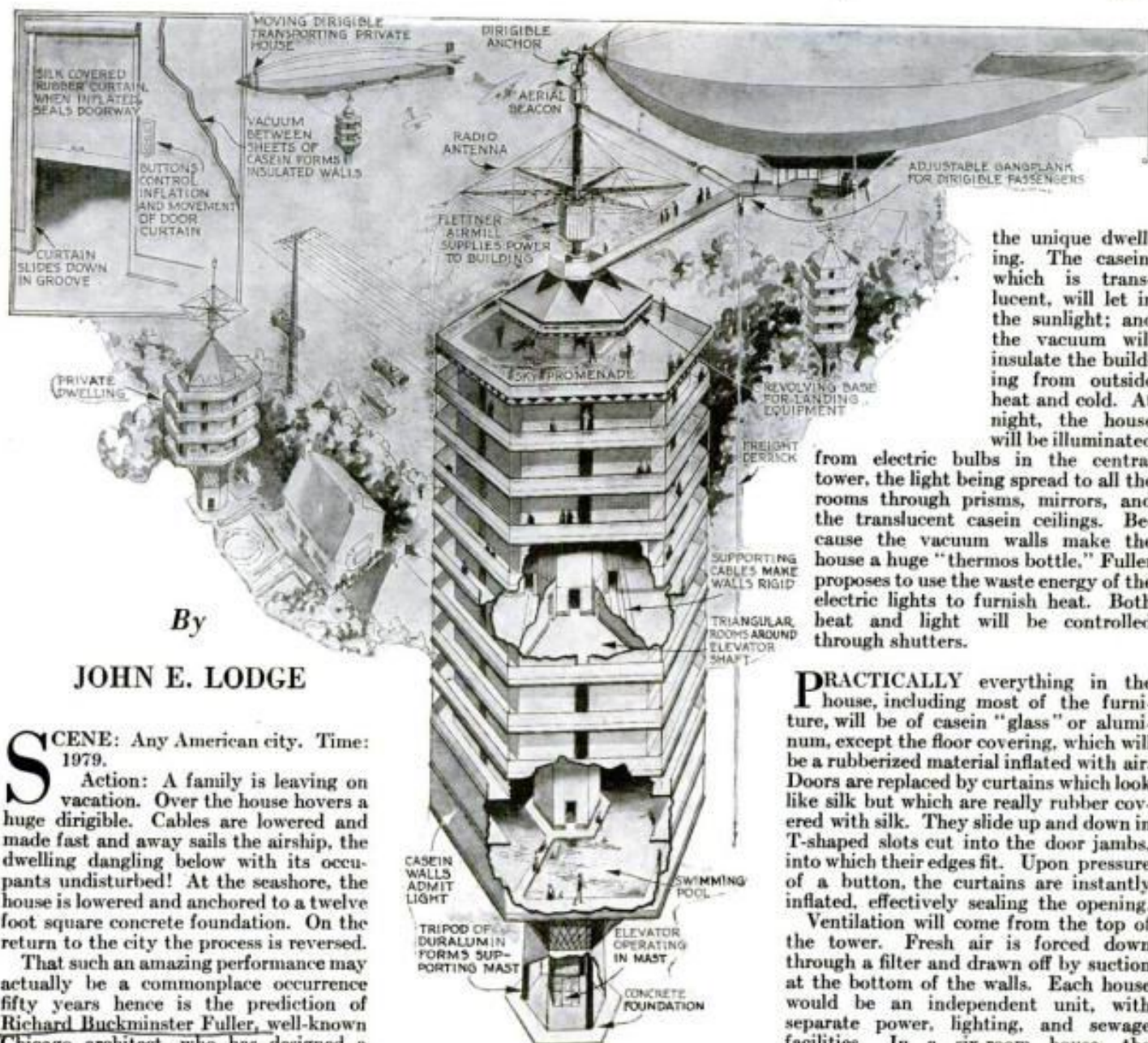
This country was among the first to investigate the possibility of airplanes being carried by airships. The experiment, conducted with a type of airship less than one tenth the size of those now building, proved the practicability of the scheme. Four years ago at the Naval Air Station in Rockaway, New York, a non-rigid airship of the C class was equipped with a cable and winch for carrying an airplane suspended from it. The plane with which the experiment was carried out was a training type known as the JN, now in service use. On the top of the wing, a ring was secured to the structure of the plane. On the end of the cable let down from the airship, a hook engaged the ring and the plane was suspended from the ship at a distance of about 50 feet below it. When the hook was released by a tripping device, the plane fell a vertical distance of about 200 feet, then recovered its equilibrium and flew to a safe landing.

The following year, in the summer of 1920, these experiments were carried further by the British. The R-33, a sister ship of the one that made a round trip from England to the United States in 1919, carried out experiments in releasing, carrying, and picking up an airplane by means of a



This towering mooring mast, has been constructed recently at Lakehurst, N. J., to anchor the first American-made dirigible the ZR-1

Plans to Move Homes by Airship



By

JOHN E. LODGE

SCENE: Any American city. Time: 1979.

Action: A family is leaving on vacation. Over the house hovers a huge dirigible. Cables are lowered and made fast and away sails the airship, the dwelling dangling below with its occupants undisturbed! At the seashore, the house is lowered and anchored to a twelve foot square concrete foundation. On the return to the city the process is reversed.

That such an amazing performance may actually be a commonplace occurrence fifty years hence is the prediction of Richard Buckminster Fuller, well-known Chicago architect, who has designed a startling "thermos bottle" home in which the floors branch from a central mast like the limbs of a tree.

The structure is hexagonal in shape, like the pagodas of the Orient. The central tower, or mast, is formed by a tripod of duralumin tubes set firmly in a concrete foundation. The floors are suspended from this mast by wire cables similar to those used in airplanes. These cables run through the walls, making them rigid.

BUT what would happen if a strong wind struck such a house? The architect replies that tests have convinced him that such a structure, rooted in concrete, could withstand any wind up to 1,000 miles an hour.

Two thin sheets of casein, the material used in molding fountain pen barrels, with a vacuum between, are to form the walls of

the unique dwelling. The casein, which is translucent, will let in the sunlight; and the vacuum will insulate the building from outside heat and cold. At night, the house will be illuminated

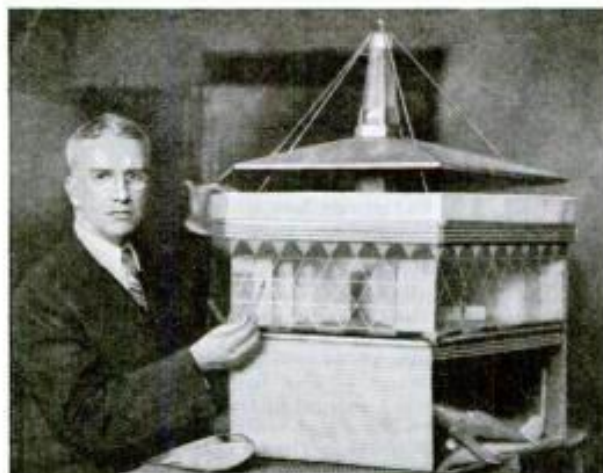
from electric bulbs in the central tower, the light being spread to all the rooms through prisms, mirrors, and the translucent casein ceilings. Because the vacuum walls make the house a huge "thermos bottle," Fuller proposes to use the waste energy of the electric lights to furnish heat. Both heat and light will be controlled through shutters.

PRACTICALLY everything in the house, including most of the furniture, will be of casein "glass" or aluminum, except the floor covering, which will be a rubberized material inflated with air. Doors are replaced by curtains which look like silk but which are really rubber covered with silk. They slide up and down in T-shaped slots cut into the door jambs, into which their edges fit. Upon pressure of a button, the curtains are instantly inflated, effectively sealing the opening.

Ventilation will come from the top of the tower. Fresh air is forced down through a filter and drawn off by suction at the bottom of the walls. Each house would be an independent unit, with separate power, lighting, and sewage facilities. In a six-room house, the ground floor would provide space for the family automobile and airplane. On the second floor would be the living quarters, reached by a small elevator running through the central tower. The top floor would serve as a roof garden.

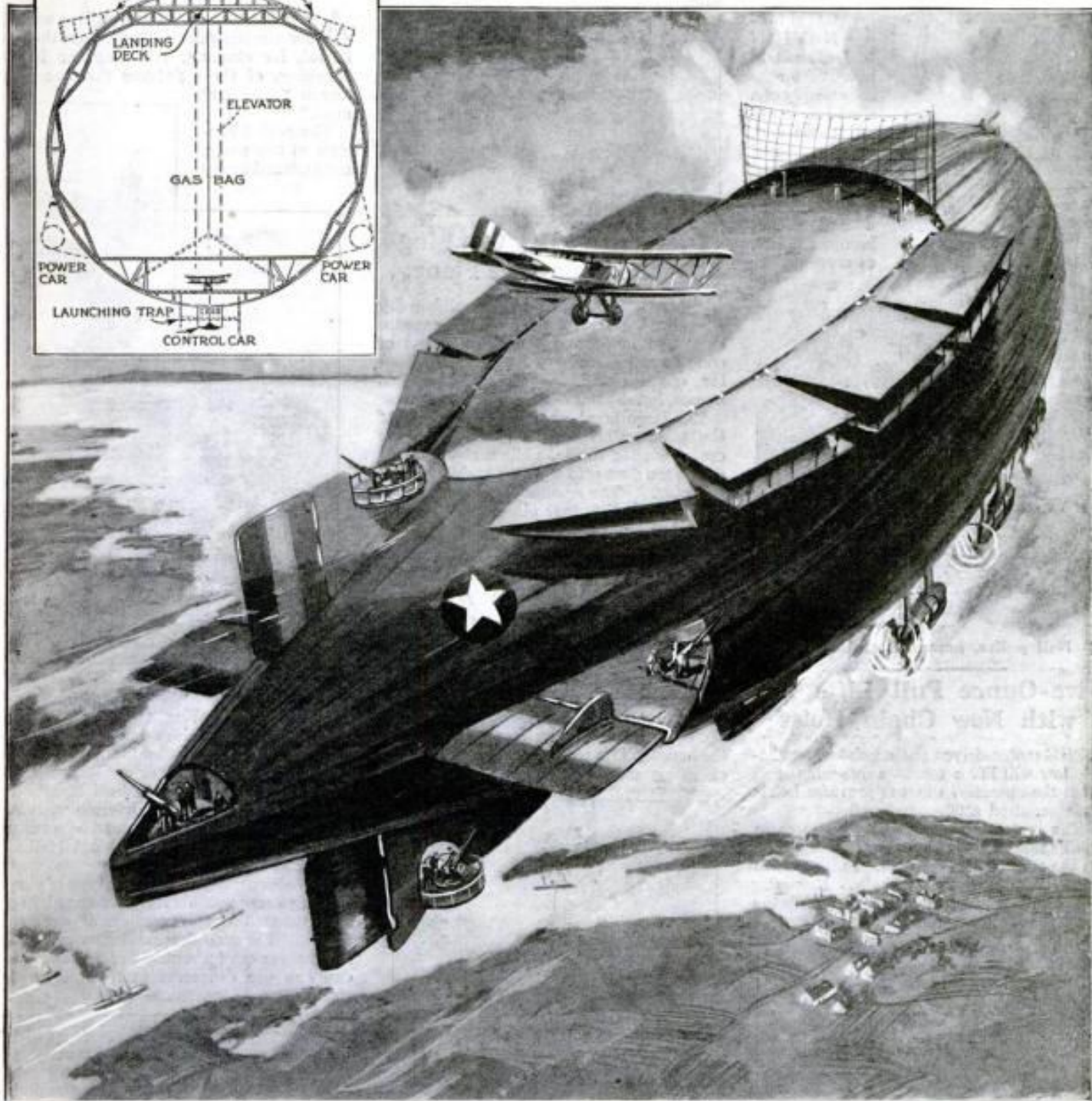
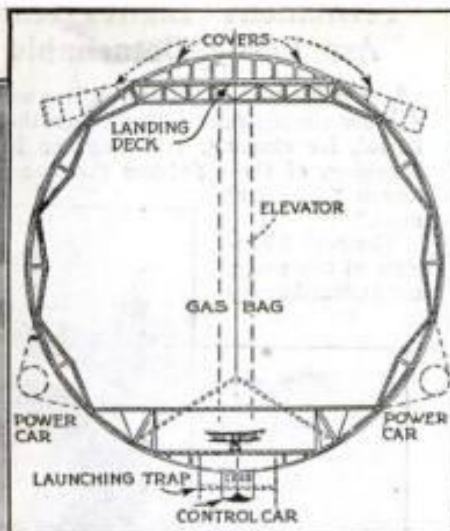
In mass production, Fuller estimates that such homes could be produced with all modern conveniences, such as pneumatic beds and sofas; electric stove, dish washer, and clothes washer; built-in radio, etc., to sell for as little as \$3,000. Moreover, the house might be delivered and "planted" in a single day.

Larger structures—twelve-deck apartment houses, tall office buildings, tower garages—can be built on the same plan, Fuller declares. Such an apartment building, with swimming pool, sky promenade, and dirigible landing platform, is portrayed here by our artist.



R. B. Fuller, Chicago architect, and model of tower home he says can be produced for \$3,000 and erected in one day. Rooms are triangular, and their casein walls admit sunlight.

A Dreadnaught of the Clouds



Our artist's conception of the aerial war-ship of tomorrow, described by Admiral Moffett. Diagram shows cross section

cable let down from the airship. These tests were similar to those carried on at Rockaway the previous summer, but were more extensive.

The plane, a Sopwith Camel, was fitted with a bridle terminating in a ring that extended above the top wing of the plane two or three feet. When the airship picked up the plane, the speeds of the two were approximately the same and it was a simple matter to engage the ring on the plane with the hook at the end of the cable. The plane was released by tripping the hook and the pilot dived, started his motor and flew away.

Until now one hazard in airship operation always has stalked like a specter at the heels of this development. Hydrogen-inflated ships carry with them the ever-present danger of fire. Many aerial disasters have been traceable to this.

The United States, possessing as it does

the only extensive helium supply in the world, is particularly favored by nature. Helium, an inert gas, is not inflammable. It has but little less than the buoyancy of hydrogen and can be produced at a cost which, though higher than that of hydrogen, is inconsequential compared with the safety and dependability gained.

We Must Conserve Helium Supply

However, we cannot afford to be as prodigal with this gift of nature as we have been with others. A well considered program of conservation of this valuable product is essential to our national welfare, from a commercial standpoint as well as from that of national defense.

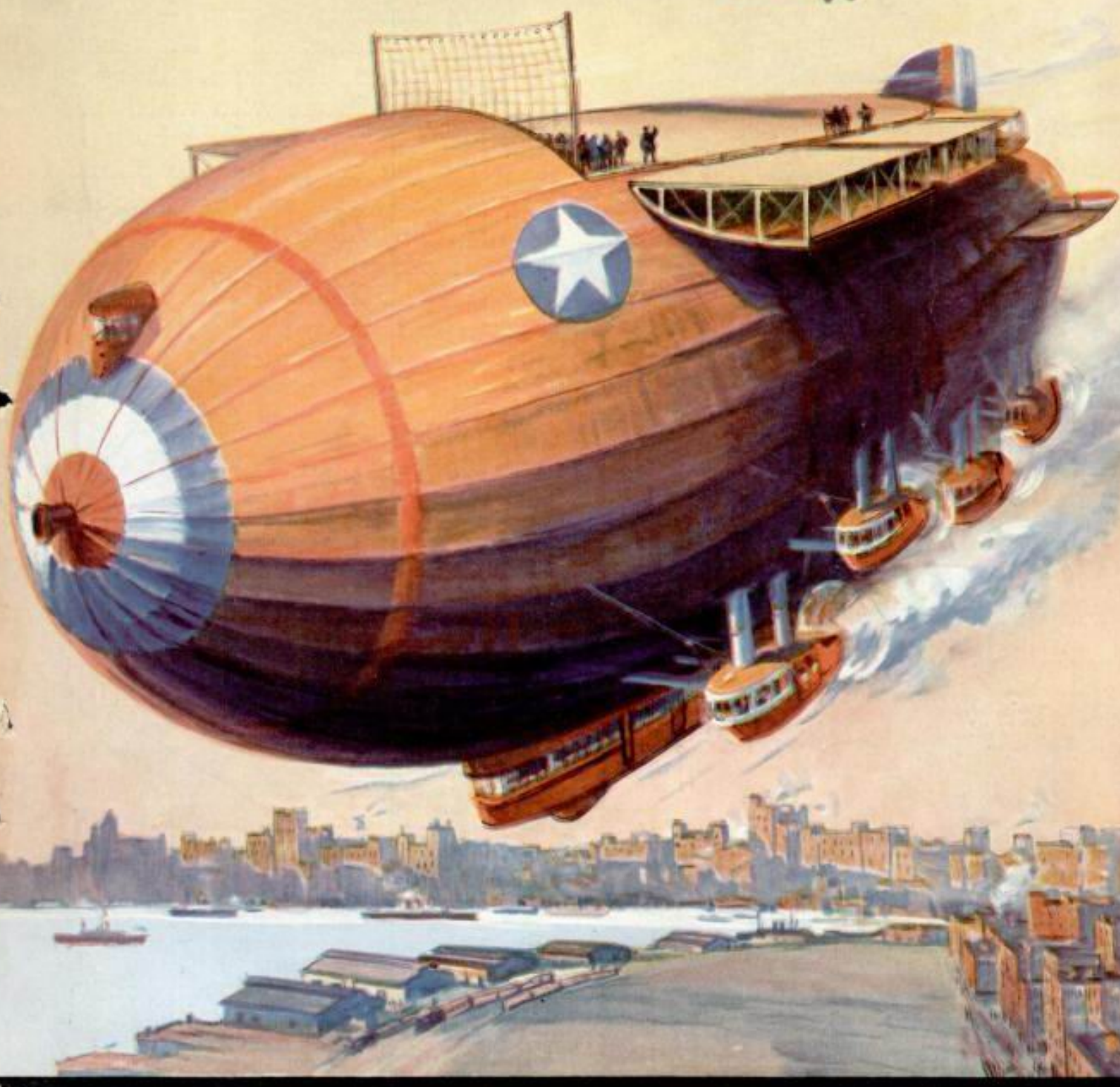
The helium airship will make this form of travel safe to a degree never before possible. It will insure low insurance rates on merchandise carried by airships.

From a military point of view, helium has placed a new complexion on the airship-airplane controversy. The airship filled with helium and defended by guns and airplanes, will be in effect a battleship with the sky as a limit. As the battleship is subdivided into watertight compartments, so the airship is made up of a number of gas cells. When a watertight compartment is punctured, the ship does not sink. This method of construction has saved ships even against the destructive effect of torpedo explosion. So the puncturing of a gas cell in the airship will not spell disaster. We may see these battleships of the air, riddled with shells, still fighting gallantly on to victory.

As a basis for the future of airship development in this country, the Navy, in constructing the ZR-1, is building wisely and well. America should be in a position to point the way to the world.

Popular Science

FOUNDED **MONTHLY** 1872



Where the World's Fastest

UNUSUAL features in the design of the German steamship *Bremen*, new speed queen of the Atlantic, are depicted on these pages. They show why she was able to race into New York harbor, the other day, with a record-smashing mark of four days, seventeen hours, forty-two minutes from the French port of Cherbourg, and then, on her return trip, to lower the record between New York and Plymouth, England, to four days, fourteen hours, and thirty minutes.

On her westbound run the *Bremen* eclipsed by eight minutes less than nine hours the record of the *Mauretania*, which had held the speed laurels of the sea for twenty-two years. The *Bremen's* average speed was 28.2 knots—about thirty-two land miles an hour. In the eastbound crossing that followed she maintained an average of 27.9 knots.

Fastest, most powerful, third longest and fourth largest merchant vessel in the world, the ten-deck *Bremen* is said to have cost \$20,000,000 to build. She is a four-screw, 50,000-ton oil burner with geared steam turbines, and can accommodate 2,200 passengers. Only the *Majestic* and the *Leviathan* surpass her length of 888 feet from stem to rudderpost, as vessels are measured for comparison.

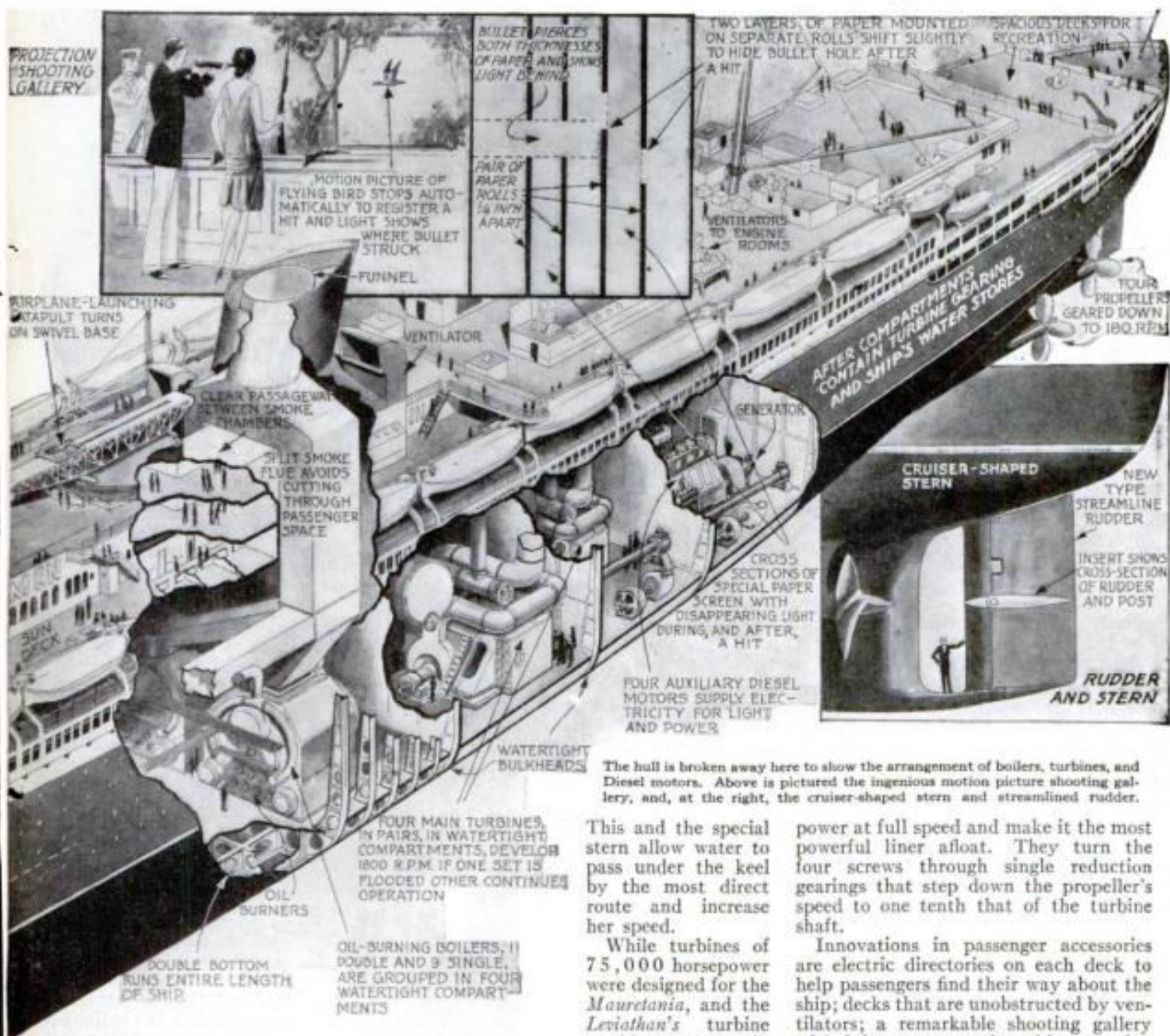
Shipbuilding, as represented in the four-day *Bremen*, has made tremendous advances since the little *Savannah*, first ship to cross the Atlantic with the aid of steam, in 1819 sailed and steamed from Savannah, Ga., to Liverpool, England, in twenty-nine days. The German liner is a new departure in shipbuilding, even from the most modern of present-day vessels.

All exposed portions of the *Bremen*—even the funnels—are streamlined to increase speed. Upper inset shows new safety mechanism for launching lifeboats. An electric directory that aids passengers to find their way about the ship appears in lower inset.

Drawn for POPULAR SCIENCE MONTHLY by
B. G. Seielstad.



Ocean Liner Gets Its Speed



The hull is broken away here to show the arrangement of boilers, turbines, and Diesel motors. Above is pictured the ingenious motion picture shooting gallery, and, at the right, the cruiser-shaped stern and streamlined rudder.

This and the special stern allow water to pass under the keel by the most direct route and increase her speed.

While turbines of 75,000 horsepower were designed for the *Mauretania*, and the *Leviathan's* turbine machinery can attain

100,000 horsepower, the four smaller high-speed turbines that drive the *Bremen* develop a total of 130,000 horse-

power at full speed and make it the most powerful liner afloat. They turn the four screws through single reduction gearings that step down the propeller's speed to one tenth that of the turbine shaft.

Innovations in passenger accessories are electric directories on each deck to help passengers find their way about the ship; decks that are unobstructed by ventilators; a remarkable shooting gallery with flying targets projected by a motion picture lantern; magnetic clocks in the staterooms, regulated from the navigating bridge; and a new type of steel davit

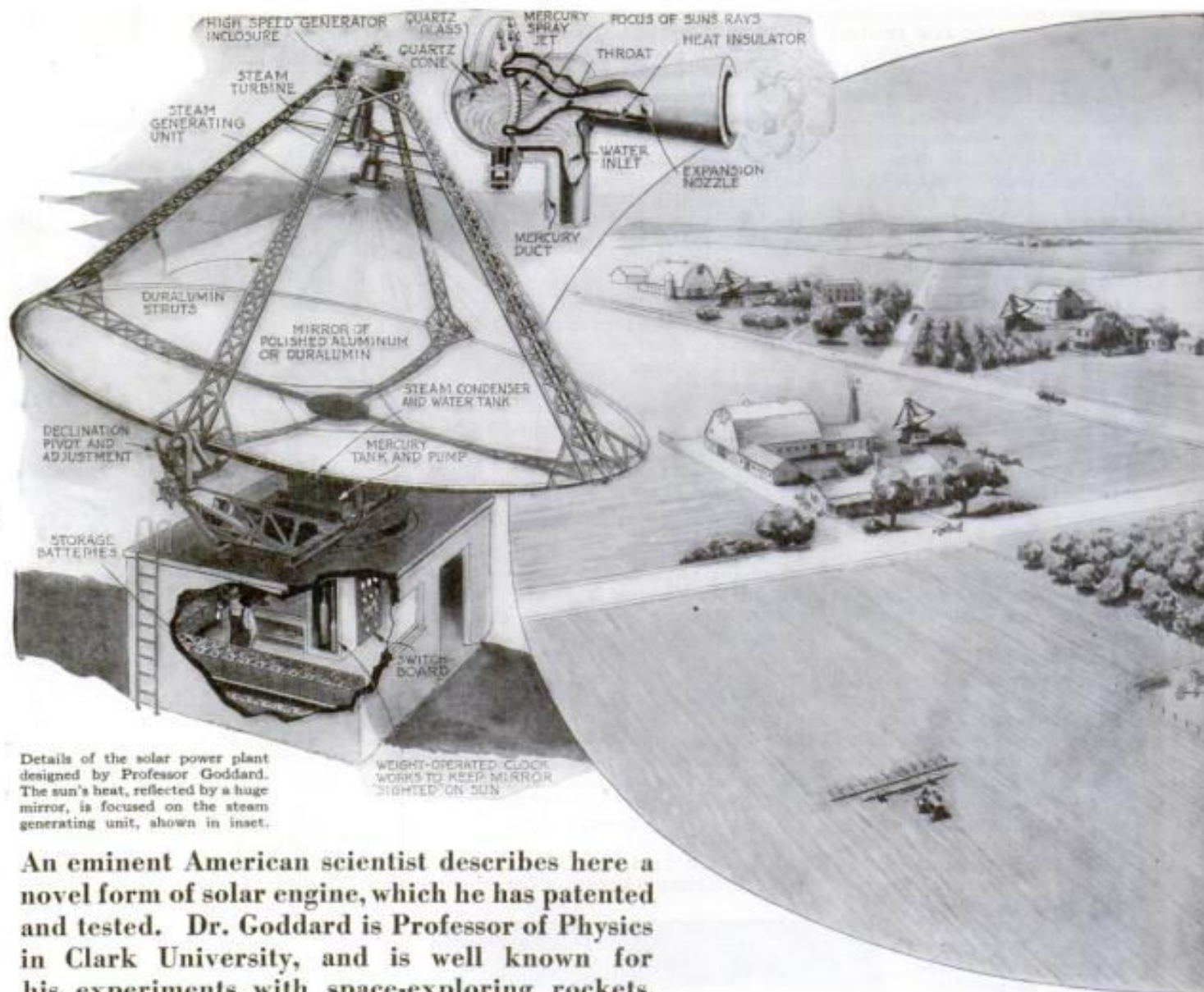
that keeps the motorized, radio-equipped lifeboats out of passenger's way on the sun deck, ready to be launched instantly merely by pressing a button. A compressed-air catapult launches a mail plane from the top deck when the ship is near port.

Every modern safety device is present. Fourteen water-tight bulkheads make the *Bremen* practically unsinkable and the boilers and turbines are in two groups.

ABULBOUS bow that presses water down instead of to the side, a new style of streamlined rudder, and a cruiser stern lifted from the sea by the propellers helped the *Bremen* to earn the title of the fastest liner. Streamlined throughout, even to the funnels, the *Bremen's* curious shape, bulging in front and tapering behind, is designed to offer the least resistance to water and air. The shape assumed by a falling raindrop is applied to the funnels and, under water, in blisters—one on each side—which give the vessel her pear-shaped bow.



Seventy years of shipbuilding progress have evolved the luxurious new *Bremen* from this ancestor of steam and sail. This old-time S. S. *Bremen* was built for the same line in 1857.



An eminent American scientist describes here a novel form of solar engine, which he has patented and tested. Dr. Goddard is Professor of Physics in Clark University, and is well known for his experiments with space-exploring rockets.

THE ordinary back yard receives more power in the form of heat from the sun than is used to heat and light the average home. A good-sized pasture may receive power equivalent to that used by all the factories of a town. Great deserts like the Sahara or the Tackla Mahan receive more heat power than is required to warm the dwellings, light the streets, and drive the machinery of all the civilized countries in the world combined.

Throughout the ages, attempts have been made to convert sunlight into mechanical power, but with little success. In every case the apparatus has proved inefficient. At last, the writer is firmly convinced, the problem will be solved by the practical application of a new solar motor he has invented and patented.

According to figures computed by Dr. Charles G. Abbot, director of the Smithsonian Institution in Washington, the sun every day supplies to the earth energy equivalent to the burning of 507,000,000,000 tons of coal. The world actually uses coal, oil, water power, and other sources of energy equivalent to about 5,000,000 tons of coal daily. Time and money are being spent in huge quantities to dig coal from mines, to pump oil from wells, and to harness streams for power, when more

A New Invention to Harness the Sun

By R. H. GODDARD

than a hundred thousand times as much power constantly is being delivered free right on the earth's surface.

While some of this solar energy is reflected back into space, it has been calculated that one square yard of the earth's surface exposed to a summer sun directly overhead receives energy at the rate of at least one and one half horsepower.

So far, the most successful attempt to harness the sun's power has been the fifty-boiler-horsepower Shumann solar plant at Cairo, Egypt. It turns into useful power only a little more than four percent of the energy received in the form of radiation. Another, the Eaneas solar engine installed at Pasadena, Calif., is even less efficient.

My new solar motor will reach an over-

all efficiency of at least fifty percent—more than twice that of the finest steam turbine electric generating plant in operation today.

The accompanying illustrations show how this new solar motor might be practically applied to supply power, light, and heat on the farms. The essential features are shown in the broken-away drawings above. Instead of the usual kind of boiler, a hemispherical end piece, made of clear fused quartz, is bolted to a hollow body. Water is pumped in and mercury under high pressure is sprayed into the water as indicated.

The fused quartz, a rock crystal material, recently has been made available in quantity. Its advantages for use in a sun motor are that it is one of the most

How solar motors might be applied to supply power, light, and heat on the farms, as suggested by Professor Goddard. Drawn for POPULAR SCIENCE MONTHLY by B. G. Seielstad.



A close-up view showing steam, generated by the sun, escaping from Goddard's motor.



Professor Goddard with sun motor, and mirror which, he says, makes water boil.

boiler. This permits the use of a metal lighter than iron for the shell, for the incoming water keeps the metal at a relatively low temperature. Because the hottest point is inside and is surrounded by the incoming water, what heat is lost from the focus point by conduction will serve to pre-heat the incoming water.

TO TEST the fundamental principle of the new engine a hollow sphere of glass five eighths of an inch in diameter was filled with water containing finely divided carbon in place of the mercury spray for the absorption of heat. This sphere was placed at the focus of a parabolic mirror one foot in diameter. When the mirror was placed in sunlight, the water boiled easily, the steam escaping in a powerful blast through a hole in the top of the sphere. As water boiled away, more was supplied by a hand pump. This small model will produce steam indefinitely as long as it is supplied with water.

The possibilities awaiting the commercial development of a really efficient solar motor are enormous. There is solid scientific backing for the belief that a solar motor of the size illustrated would produce upwards of thirty useful horsepower when operating under a clear sky between the hours of ten in the morning and three in the afternoon—the time when sunlight is at its maximum power in the United States. That amount of power, converted into electrical energy, would far exceed the requirements of a large farm; the unused current could be employed to charge batteries. These, in turn, could maintain the normal current supply on cloudy days and at night. If the mirror were 100 feet in diameter, the output, figured conservatively, would be 650 horsepower.

NOT everywhere on earth, of course, does the sun shine every day, and in no spot does it remain directly overhead. But even so, it is fair to assume that each twenty-foot mirror concentrating available sunlight on an engine fifty percent efficient would yield, year in and year out, a twenty-four-hour average of at least four horsepower. In sunny tropical regions, such as the Sahara, the average yield would be much greater. Whether to use a large number of such small mirrors or a smaller number of large mirrors measuring a hundred feet or more in diameter, would be merely a question of ease of handling and of comparative cost.

The reasons why the new solar motor will operate with such remarkable efficiency are best understood by observing where the losses occur in present engines such as the steam turbine plant and the gasoline engine.

The secret of efficient operation of any heat engine is high temperature. That is why the gasoline engine, with its extremely hot exploding charge, is more efficient than the ordinary steam engine. That also is why engineers are designing steam plants to use higher and higher boiler pressures. Modern steam generating plants commonly use boiler pressures as high as 500 to 750 pounds, whereas steam plants built years ago rarely used a pressure above 150 pounds.

But the

(Continued on page 157)

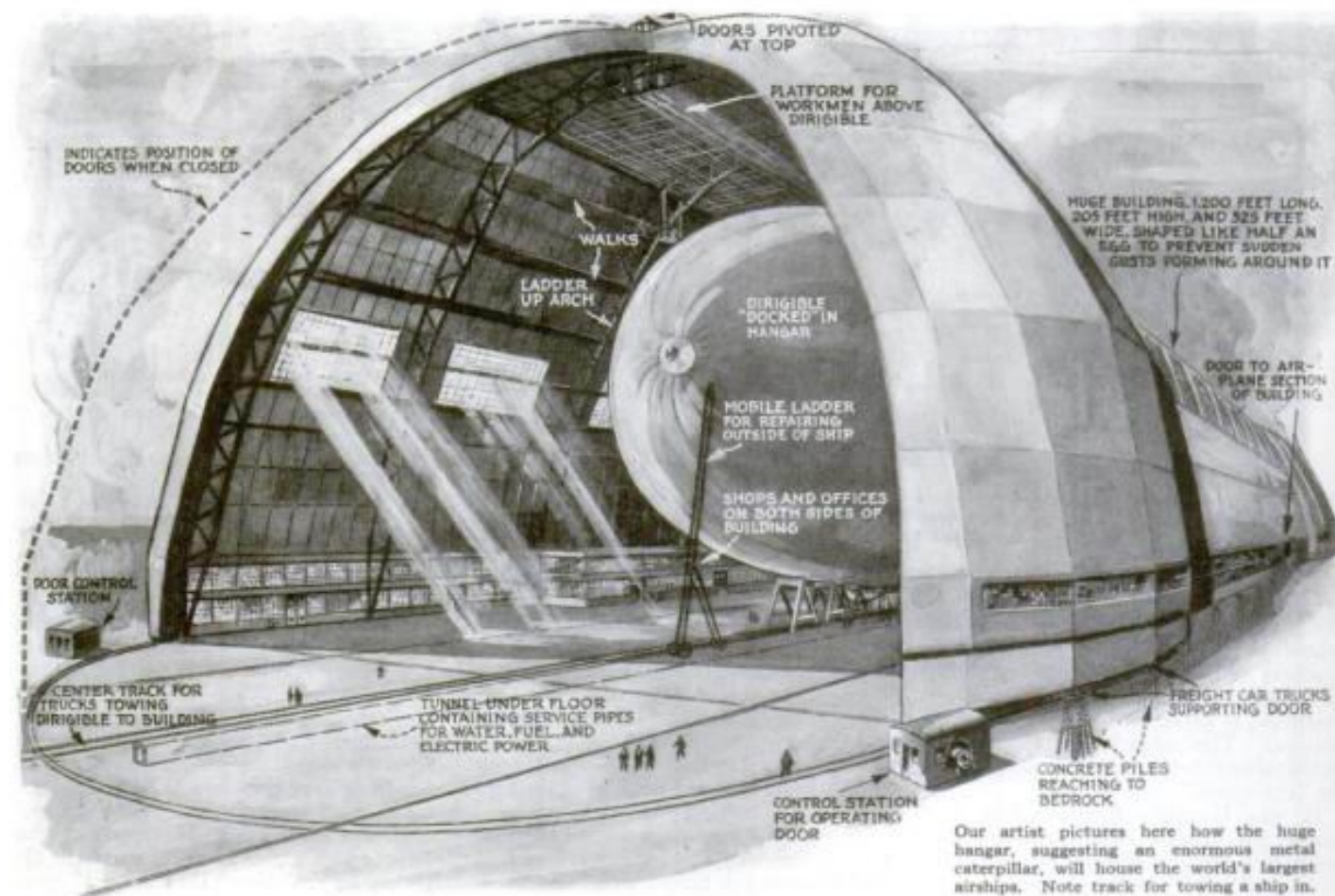
transparent materials known; it will not crack when subjected to heat as does ordinary glass, and it will stand enormous temperatures before it melts.

A mirror of large size is focused on the fused quartz so that the point of greatest heat is where the spray of mercury forms a screen in the water. The water itself, being transparent, will not absorb the heat, but the mixture, being opaque to light, will absorb all the heat instantly. The resulting tremendously high temperature will convert the metallic mercury into mercury vapor at a correspondingly high pressure, and the water will be converted into steam at high pressure. By feeding these gases directly into a turbine, the heat can be converted into mechanical power without the usual losses caused by friction through long sections of piping.

IN A nutshell, the new solar engine is like a hollow crystal ball into which water passes at one end and from which steam issues directly into a turbine.

A feature of the design is that the quartz end piece can be shaped so that every ray of light from the mirror will strike it at right angles. This will prevent loss of energy by reflection. Another advantage is that the hottest point is inside instead of outside, as with the ordinary

A Nine-Acre Nest for Dirigibles



Our artist pictures here how the huge hangar, suggesting an enormous metal caterpillar, will house the world's largest airships. Note track for towing a ship in.

Mammoth Hangar for the Navy's New Airships Would Almost Swallow the National Capitol!

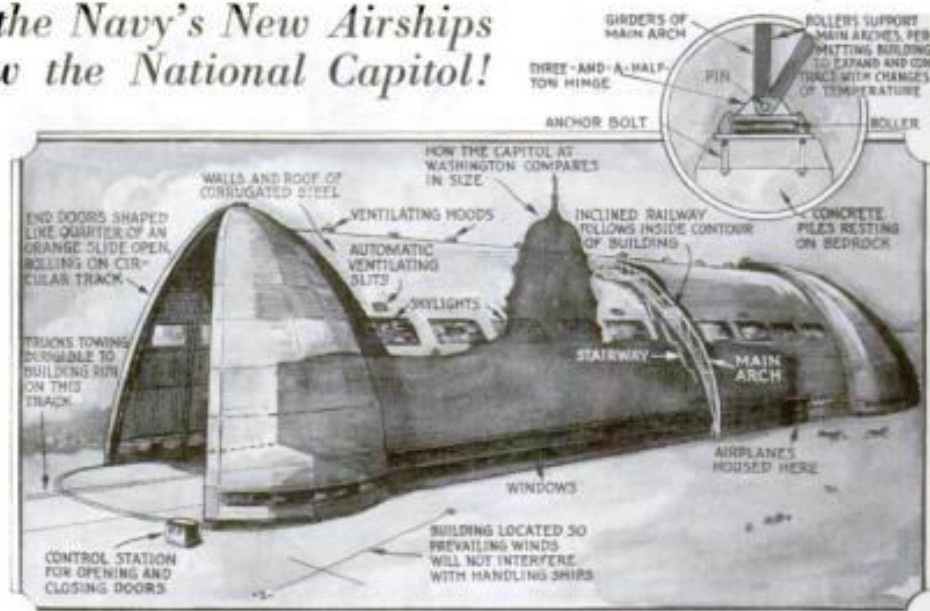
By

ARTHUR A. STUART

WITH the British sky leviathan, the *R-100*, groomed for its flight to America; its sister ship, the *R-101*, undergoing tests in England; the *Graf Zeppelin* tackling a round-the-world trip, and work commencing upon the world's largest hangar at Akron, Ohio, in which are to be built two record-breaking air monsters for the U. S. Navy, public attention again is attracted to lighter-than-air craft.

Interest in the United States at present is centered upon the construction, by the Goodyear-Zeppelin Corporation, of the titanic shed in which the two Navy dirigibles, the *ZRS-4* and the *ZRS-5*, will be built and housed. Each of these aerial dreadnaughts will be larger than the *Graf Zeppelin* and the *Los Angeles* combined. Six million five hundred thousand cubic feet of helium will lift each of the immense silver cigars into the air when they are completed in 1933.

Their magnitude is emphasized by comparison with the airships now in



The hangar compared in size with the national Capitol. Curious orange-peel doors, each weighing 800 tons, will be moved by motors. Inset shows provision for expansion and contraction.

existence. The Navy's *Los Angeles*, largest dirigible in America, has a gas capacity of 2,500,000 cubic feet; the *Graf Zeppelin*, latest product of the famous factory of Friedrichshafen, Germany, 3,700,000; and the *R-100* and the *R-101* each 5,000,000. Thus, either of the two American dirigibles will exceed their

nearest rivals by a million and a half cubic feet of lifting gas.

Besides their great size, the airships will be remarkable for radical innovations in construction. Motor gondolas are eliminated. The control cabin will be the only break in the perfect streamlining of the long hulls. Eight motor compartments

will be located within each airship, the shafts of the motors extending outside to turn the propellers, which can be swiveled to a horizontal position to give an upward thrust when the dirigible is rising, or thrown into reverse in this position to pull down in landing.

AS A protection against attack, these flagships of America's aerial navy each will have machine gun openings at several points in the envelope. Near the center of the bottom of the hull five fighting planes will ride in a "kangaroo pouch" or carrying compartment. A special trapeze device is being perfected to lower them into the air for taking off and to catch them on their return from speedy observation or combat flights. Thus, these remarkable dirigibles are to be flying hangars as well as sky dreadnaughts.

In each main ring of the rigid duralumin framework, ladders will circle the hull and four corridors will lead from one end of the ship to the other, so that inspection of virtually any part of the dirigible may be made in the air. With all eight motors opened up, the dirigibles will speed eighty-six miles an hour. The fuel supply will allow a nonstop voyage of 8,000 miles—the distance an average motorist covers in a year of driving!

While foreign dirigibles use highly explosive hydrogen as lifting gas, American airships employ helium. The United States is the only country now producing an independent supply of this nonburnable, lighter-than-air gas.

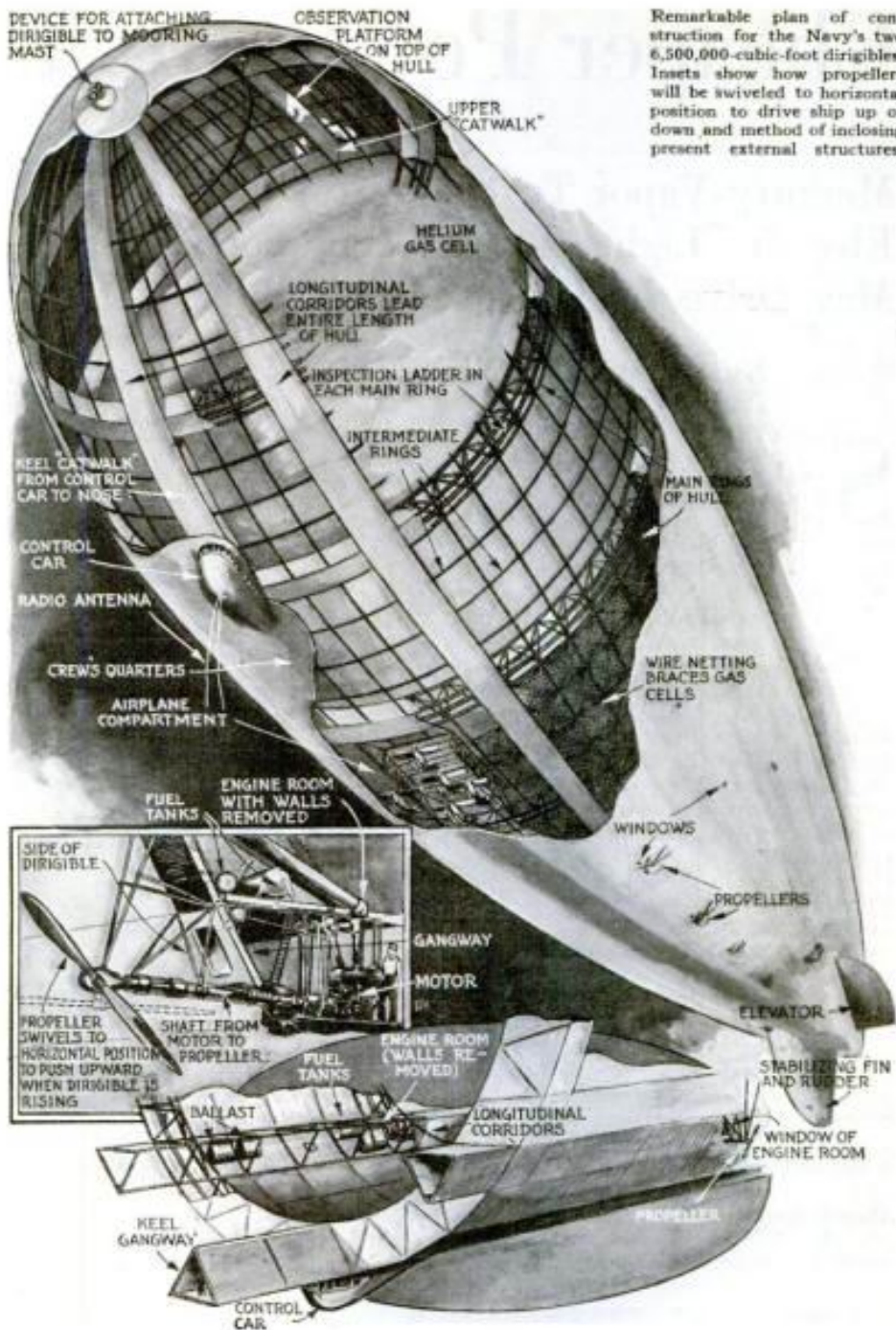
Before these two mammoths of the sky can be built, a shed big enough to hold them must be constructed. For this purpose, the largest building in the world is rising in the center of a field on the outskirts of Akron, Ohio.

Seen from afar, its fantastic design will suggest a monstrous metal caterpillar. For the sides of the long shed are to be rounded to prevent the formation of disturbing air currents and sudden wind gusts, such as are created by high vertical walls, and which would make dirigible launching hazardous.

Nine acres of level floor space will lie under the single roof. Within the gigantic building fourteen football games could be played at the same time and the whole national Capitol at Washington, except the tip of its dome, would be swallowed up within it! The highest skyscraper in the world, the Woolworth Building, and the Washington Monument both could lie side by side on the floor and leave space for a couple of steamships beside them!

SUPPORTING this mountain of steel, 1,200 feet long, 325 feet wide, and 205 feet high, will be concrete piles reaching to bedrock. The arched design of the building will leave the interior entirely free of obstructing pillars and columns, and will allow working platforms to be placed at various heights up the sides of the walls to permit inspection and repair of the dirigibles while they are "docked."

To preserve the rounded contour of the structure, strange doors, each like the skin of a quarter of an orange, will open and close on semicircular tracks at the ends of the building. Each of the four doors—two at each end—will weigh 800 tons,



Remarkable plan of construction for the Navy's two 6,500,000-cubic-foot dirigibles. Insets show how propellers will be swiveled to horizontal position to drive ship up or down and method of inclosing present external structures.

three times as much as the average passenger locomotive! To move the massive portals, four 125-horsepower motors will be required; and, to slow them down, special electrohydraulic brakes must be applied. The doors will be supported on the tracks by a series of trucks similar to those used on freight cars. Every time the great doors at one end of the building yawn, the opening is 180 feet high and 240 feet wide at the bottom—a space through which a fifteen-story building might pass.

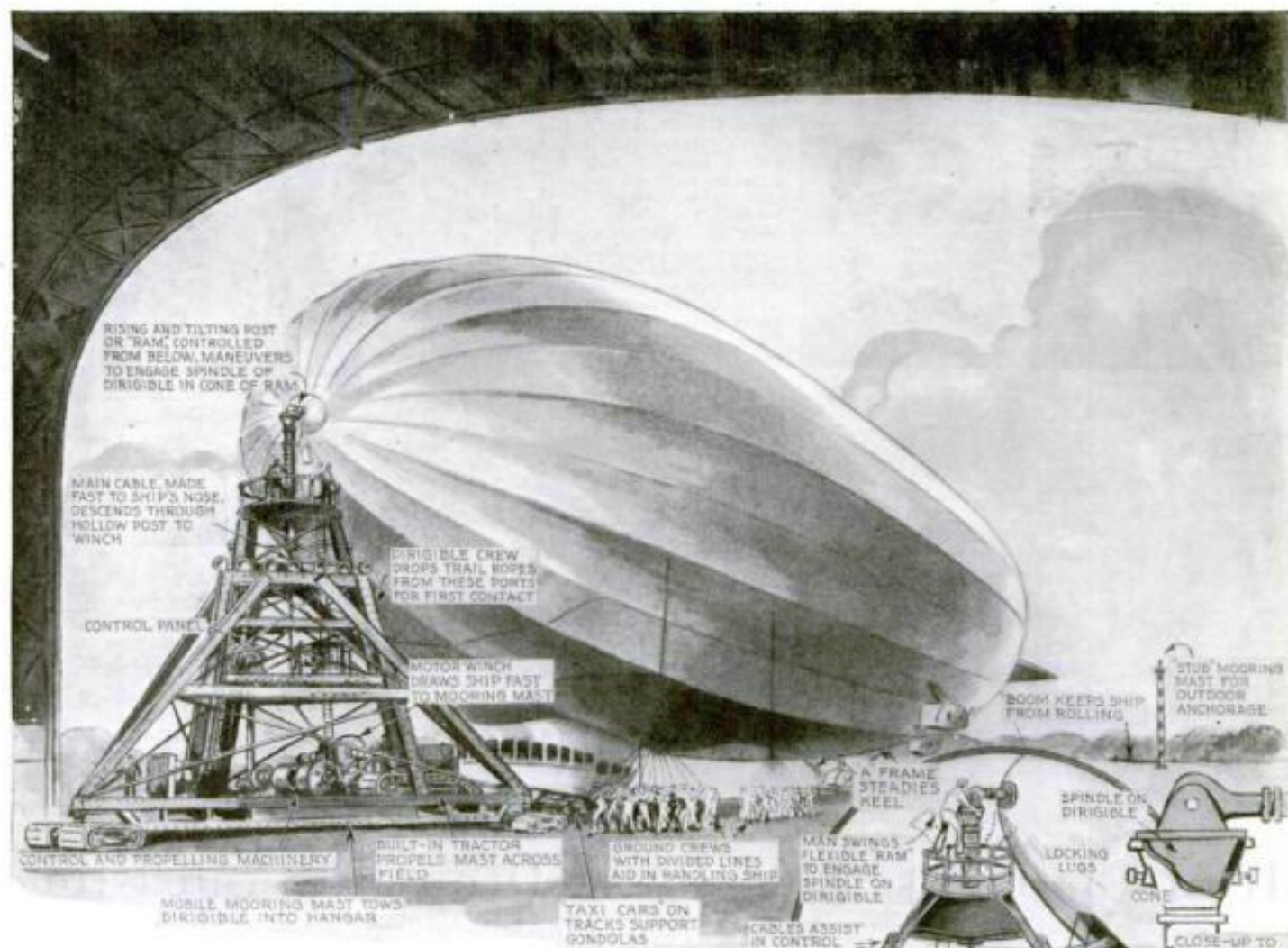
But perhaps the most amazing feature of the design is one that permits the whole structure, with its acres of corrugated steel roofing, to stretch and change its size, to expand and contract with alterations in temperature! This is made possible by placing rollers between the main arches and the concrete supporting piles and by hinging the arches at their bases. Under a blazing midsummer sun, with the thermometer standing at 100 degrees F., the metal building will

stretch to a length a foot greater than in zero weather. This constant warping back and forth would shorten the life of the structure if no special arrangement were made to take care of it.

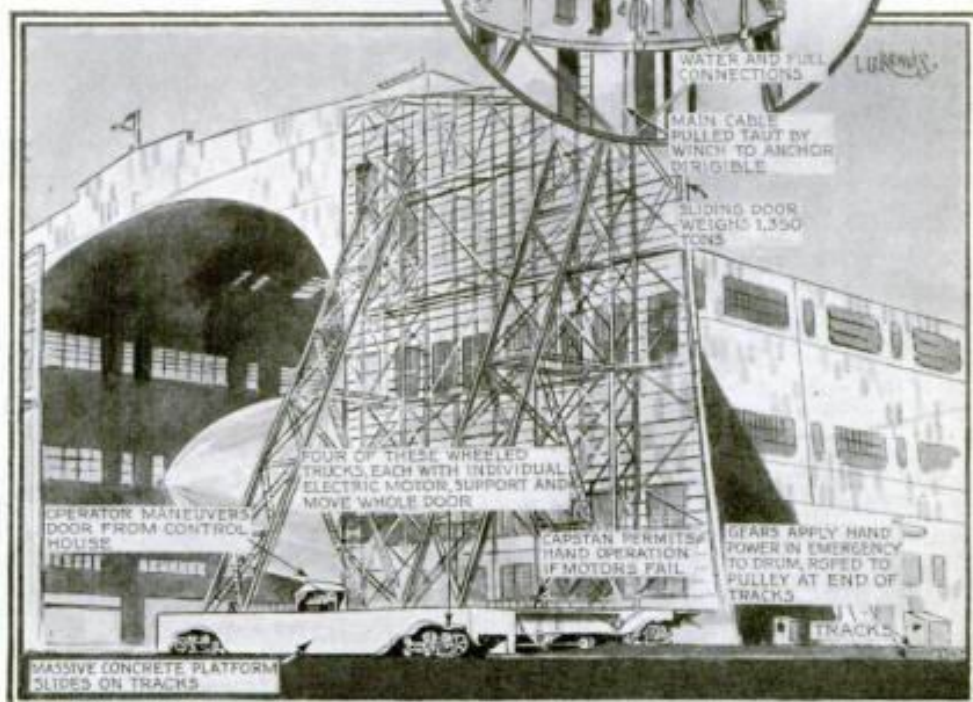
FUEL, power, and water will be supplied to the various parts of the farm-sized floor of the building through an underground tunnel running beneath it. A mile of railway track will pass through the shed to the far sides of the landing field. Upon it will travel the wheeled "land tugboats"—railway trucks to which the airships will be anchored for towing them to and from their huge berth.

While construction of this remarkable dirigible shed is being pushed forward in America, word comes from Germany that a five-million-dollar Zeppelin hangar of radical design is planned. This great airship shed is to revolve on a turntable so it can be pointed to avoid cross winds when sky liners leave or approach its doorway.

How Air Giants Are Parked



Drawn especially for
POPULAR SCIENCE
MONTHLY
by L. U. Rousie



Each huge hangar door rests upon a massive concrete platform running on railroad tracks and driven by four twenty-five-horsepower motors, geared to the car wheels. They open or close a door in twelve minutes. Above, in circle, dirigible is shown being restocked with gas, fuel, and water while moored to the mast.

THE *Graf Zeppelin's* return to America and the scheduled arrival this year of the new British air mammoths *R-100* and *R-101* raise anew the tremendous problems involved in docking a huge airship. On this page our artist pictures how ingeniously these problems are being solved at the Lakehurst, N. J., Naval Air Station.

Above is shown a mobile mooring mast—a "land tugboat" for dirigibles, designed to meet a dirigible and tow it to the hangar. At Lakehurst the mast is mounted on rollers and pulled by a tractor. Here the artist has incorporated caterpillar treads in the mast itself—an improvement which is being considered by the Navy Department.

When a dirigible approaches a mooring mast it makes first contact with the ground crew by dropping 325-foot trail ropes. Then the main mooring cable is lowered and secured to a line that passes down the hollow column of the mast. A winch draws the main cable taut until a cone-shaped spindle on the airship's nose nuzzles into a flexible post or "ram" in the mooring mast itself, as pictured in the circle.

The lower illustration shows how the ponderous 1,350-ton doors of the Lakehurst hangar slide open.

Ocean Airports of Artificial Ice

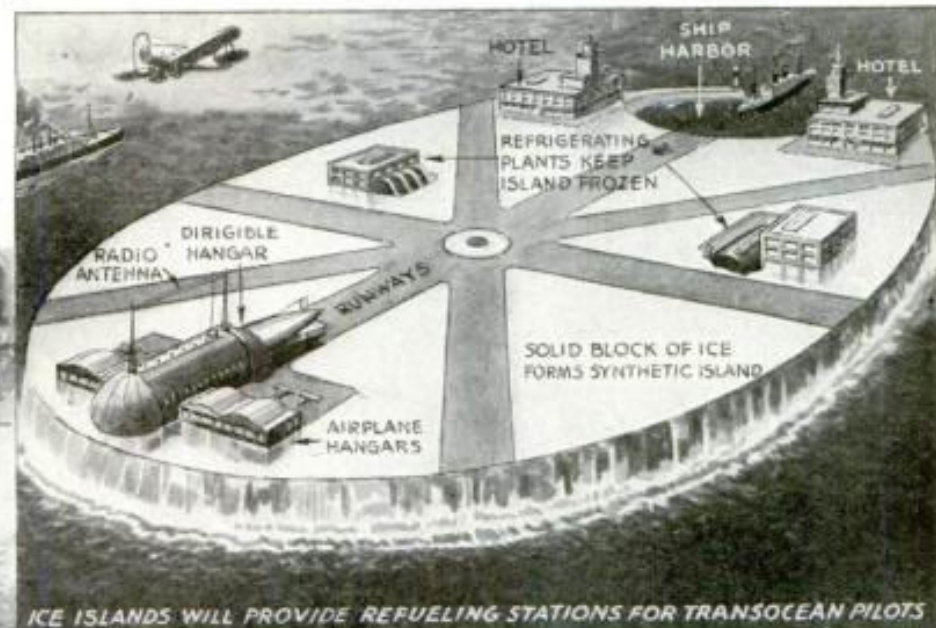
*Daring Project Would
Dot Sea with Islands
Kept Solidly Frozen*



By artificial refrigeration, a German inventor would produce breakwaters at danger points near shore as shown in drawing above. Pipes with freezing mixture are seen in cutaway portion.

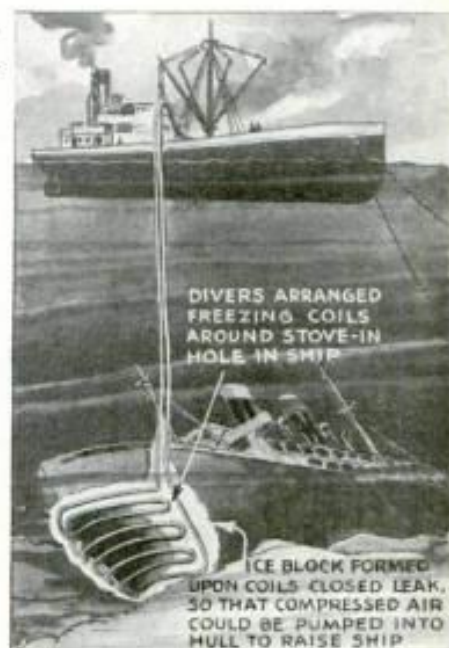
ISLANDS of ice for ocean flyers, resting on the sea bottom and kept firm by refrigerating plants, are visioned by a German engineer. Such man-made ice cakes, he declares, could be produced for transocean airlines at a fraction of the cost and time involved in other proposals for "sea-dromes" or midway stations.

Engineers have hitherto overlooked ice as a building material, according to Dr. A. Gerke, of Waldenburg, Germany, originator of the startling plan. The great ice caps of the polar regions prove that ice may be as solid and lasting as rock. Modern advances in refrigerating science, Dr. Gerke maintains, now forecast permanent structures built of ice in temperate regions.



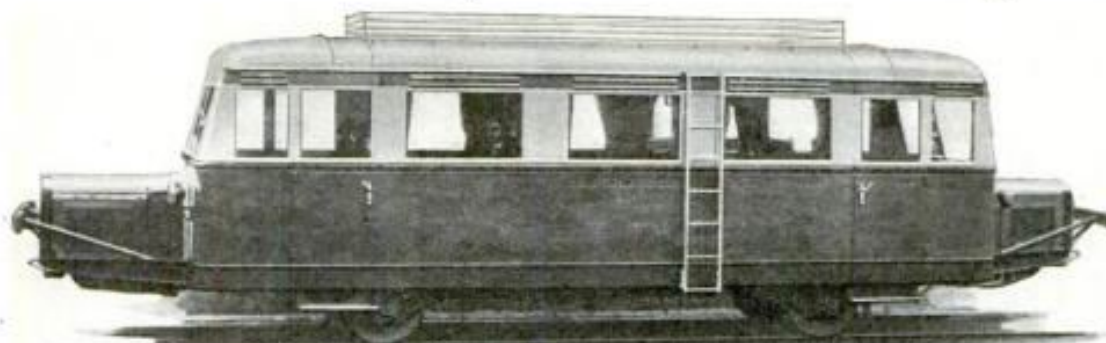
Island of artificial ice proposed as mid-ocean landing field for aircraft, with a harbor to shelter the supply ships that serve its needs.

To create an island airport, Dr. Gerke would anchor two or three ships equipped with refrigerating plants at a suitable shallow spot. Divers would lay a network of vertical and horizontal pipes to the sea bottom. As a freezing mixture is pumped through the pipes, a solid island of ice would take shape. A permanent refrigerating plant on the island would thenceforth keep it frozen—easy once the ice cake is formed, according to Dr. Gerke. Artificial islands for deeper spots could be formed near shore, towed to sea, and anchored, he believes. He also points out that two years ago a sunken ship was raised in the Lake of Zurich, Switzerland, by forming a block of ice within the hull to plug a large leak.



How a salvager plugged hole in a derelict with artificial ice and raised the vessel.

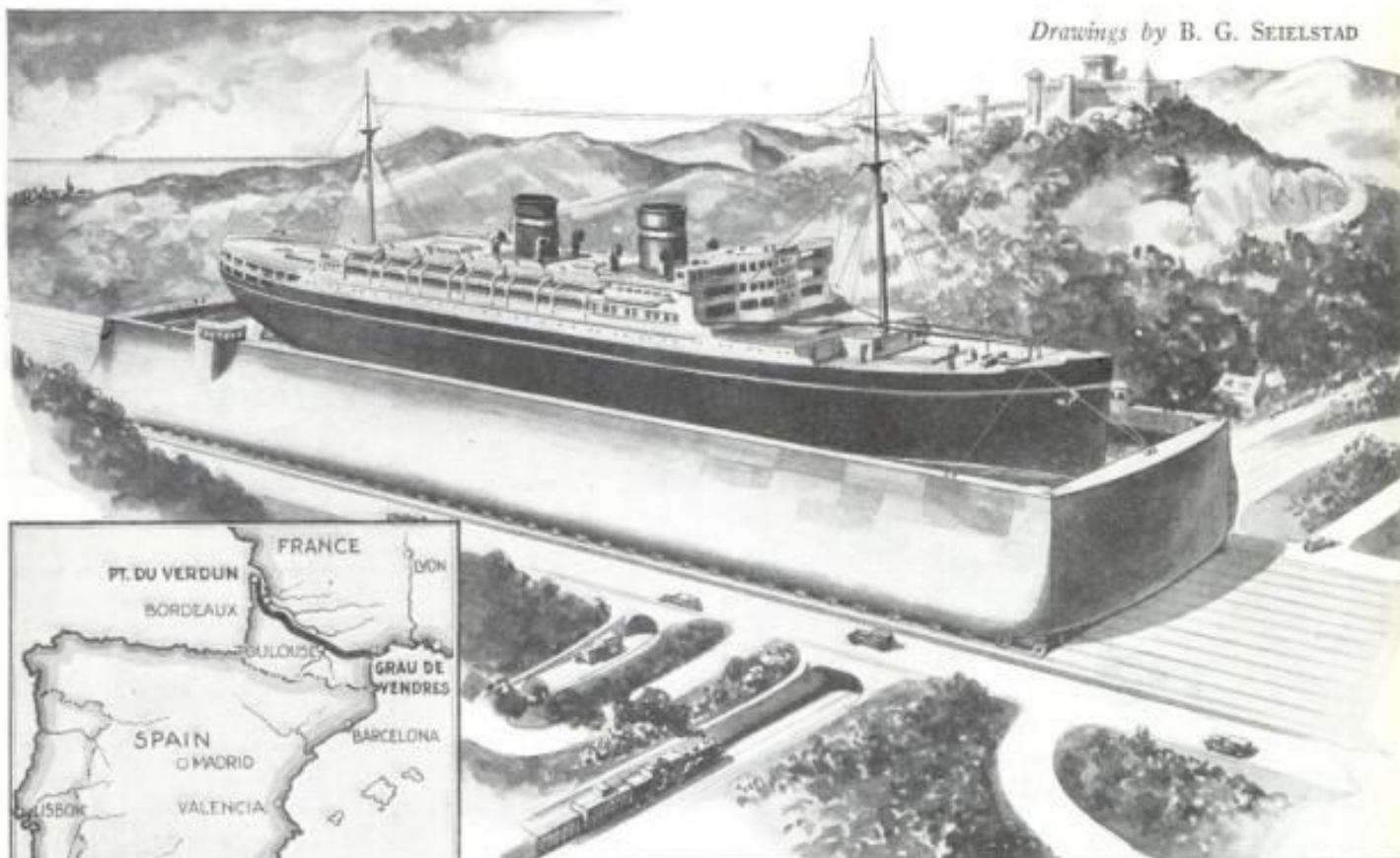
First Two-Way Rail Bus Now Running in Germany



A GERMAN railroad has recently put into operation what is believed to be the first two-way rail bus in the world. At each end of the body, which is of conventional bus construction with flanged wheels, is a driver's compartment and a complete power plant. Thus the bus may be driven in either direction without reversing it on a turntable. The odd vehicle is designed to carry thirty-four passengers. Baggage goes on the roof.

Giant Railway for Ocean Liners

Drawings by B. G. SEIELSTAD



Heavy black line running from Verdun to Grau de Vendres marks route of proposed liner-carrying railway which would solve one of France's transportation problems.

CAN an express railway be built to carry the world's largest ocean liners bodily across France, between the Atlantic Ocean and the Mediterranean Sea?

An engineer named Mahl puts forward this proposal to solve one of France's outstanding maritime problems. Today steamships must make a circuitous, time-consuming journey around Spain to get from one body of water to the other. So often discussed and debated that it already has a name, "The Canal of The Two Seas," is a long-cherished French project of a deep waterway between the country's two coastlines. Mahl's bold alternative would obviate the need of such a canal. His ship-carrying railway, he declares, could be constructed at half the cost of the canal.

"Cars" for this amazing railway would be giant reservoirs of water rolling upon trucks—literally, "canal locks on wheels" as the inventor describes them. Each would hold enough water to float a vessel twice the size of the *Ile de France*. According to the inventor's plans, the car will be provided with ten axles, each bearing twelve wheels rolling upon rails nine feet apart and embedded in concrete. The total length of the car is 650 feet, or nearly three city blocks.

The projected route of the railway is between the point of Verdun, on the At-



Drawing suggests manner in which the gigantic railway cars would take on board ocean-going vessels and rush them across France from the Atlantic to the Mediterranean in a few hours

lantic coast, and Grau de Vendres, on the Mediterranean—a distance of about three hundred miles. At each terminal, an inclined extension of the railway will run down into the water. When a liner wishes to be transported, and the fee for passage has been paid, one of the reservoir cars will descend the inclined rails until its wheels are well below the surface of the water. A swinging bascule door at the forward end will be open during this process, allowing water to enter the car. The liner is then maneuvered by tugs into the car. The bascule door is closed and made watertight. Slowly the car remounts the incline with its massive burden of water and ship.

Once on level ground, the car moves across country under the impulse of its self-contained electric motors at a speed greater than that possible to ships in a

canal. When it arrives at the destination, the liner is set down in the water by reversing the process used in picking it up. Again the bascule door swings open, and the vessel steams out and on its way.

To build more than one of the big tracks required by this giant railway would be of prohibitive cost. Therefore turn-outs will be constructed at certain points along the right-of-way, where one of the cars can be shifted laterally off the track to allow the passage of another going in the opposite direction.

Despite the boldness of Mahl's plan, it has captured the attention of engineers seeking a solution to France's waterway problem. In its favor is pointed out the immensity of the task of building such a canal as has hitherto been proposed—a "big ditch" that would have to be nearly ten times as long as the Panama Canal.

POPULAR SCIENCE

NOVEMBER

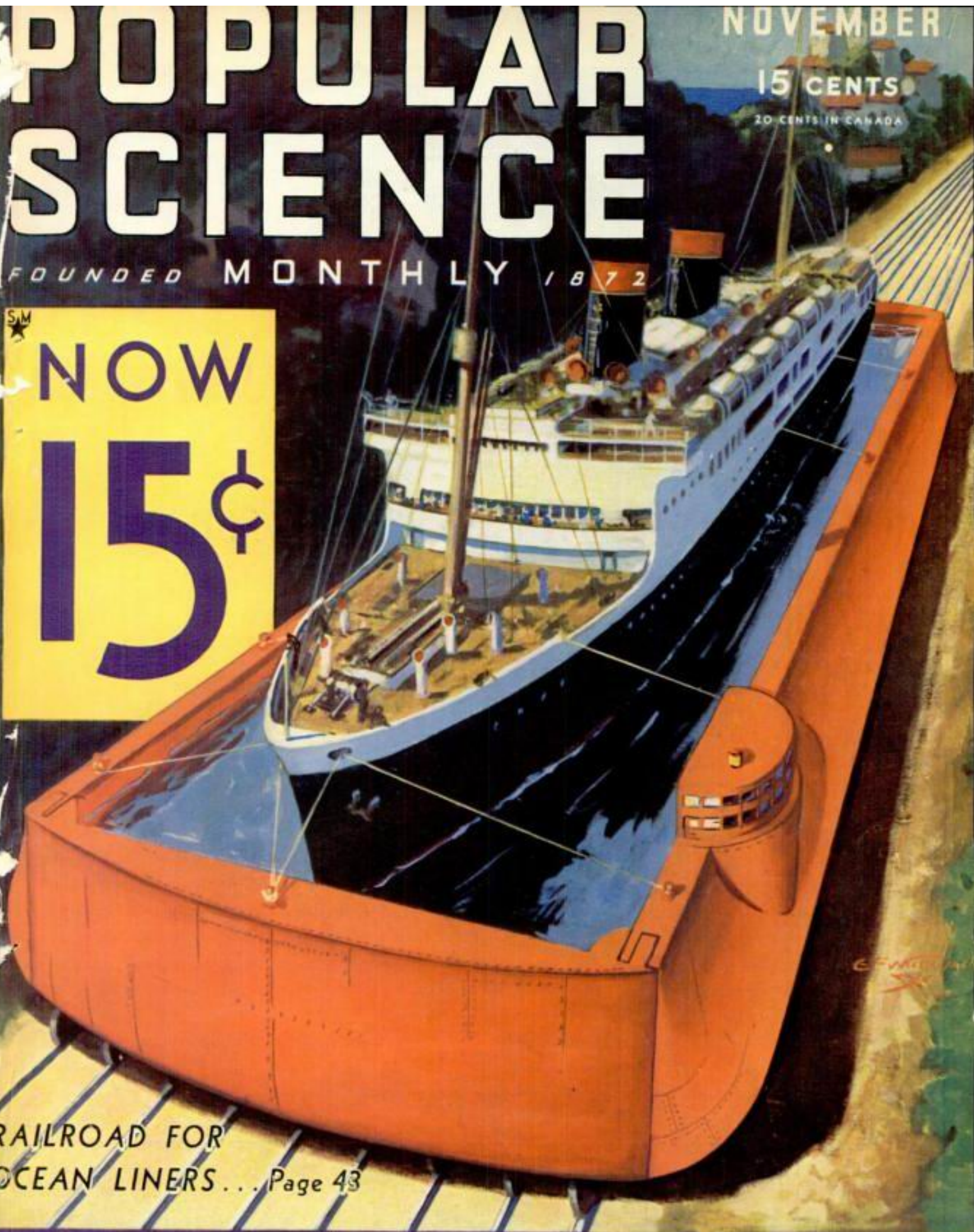
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RAILROAD FOR
OCEAN LINERS... Page 43

NEW INVENTIONS • MECHANICS • MONEY MAKING IDEAS
55 HOME WORKSHOP PLANS AND HINTS • 350 PICTURES

Cylinders Replace Wings in Plane

JETS of air, sucked in at the front and expelled at the rear of huge tubes, are the unconventional means advanced by a Glendale, Calif., inventor for lifting and propelling an airplane. He has designed and patented a wingless craft, employing this principle, which he maintains will be able to rise and descend vertically and to hover motionless aloft. According to the inventor's plans, a propeller and motor are installed within each of two tubes, which in turn are so mounted above a standard airplane fuselage that they may be swung by the pilot to any angle. For a take-off, the tubes are to be operated in a perpendicular position, thus providing a vertical lifting force. Once in the air, the pilot would tilt the tubes ahead, in order to cause the plane to travel forward. An auxiliary propeller on the fuselage is provided to aid in forward travel, while rudders steer the plane.

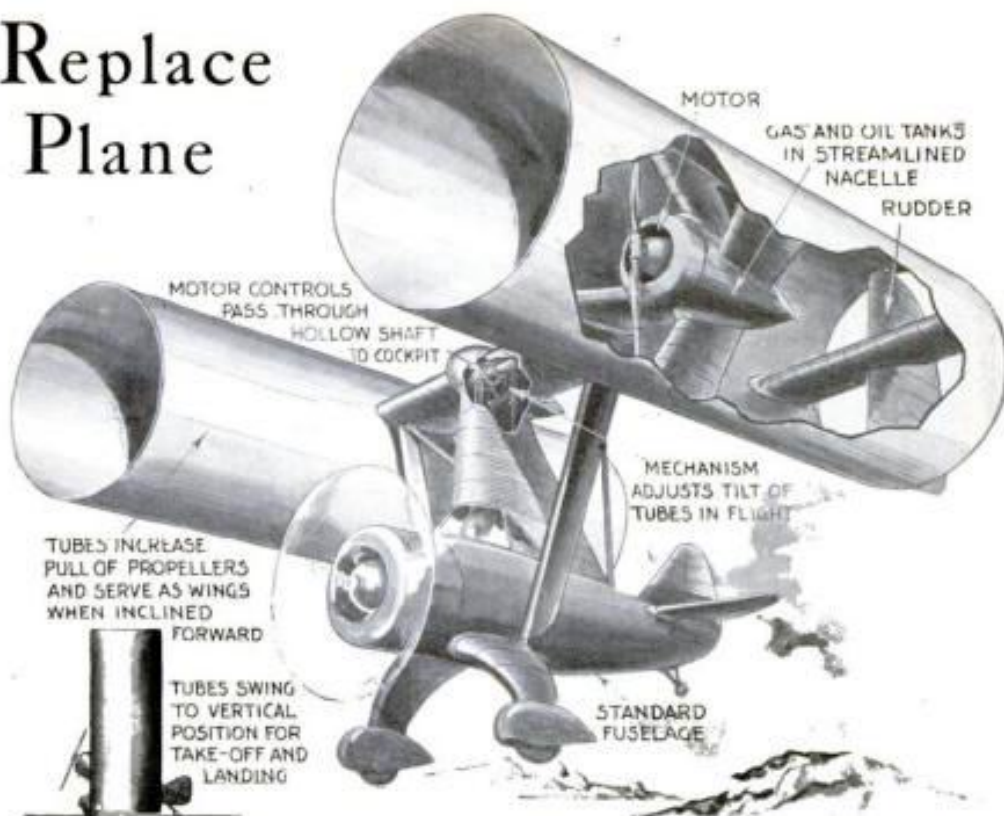
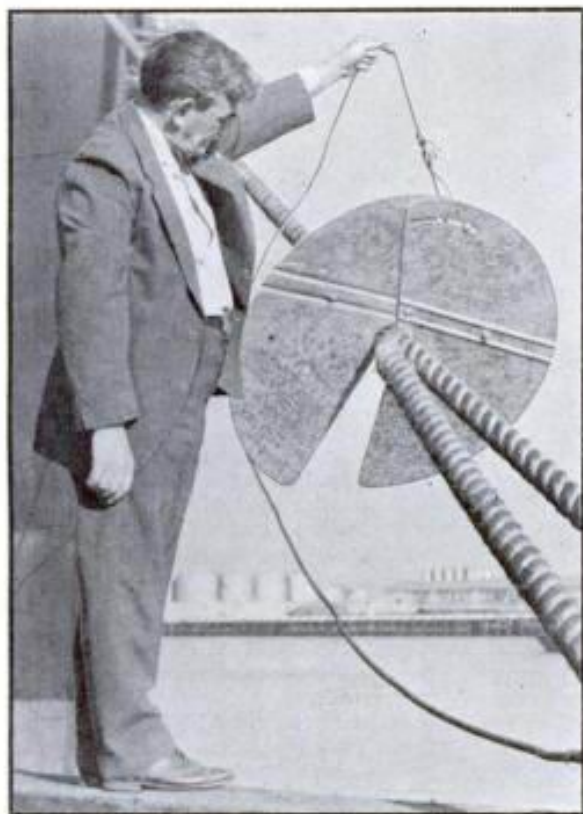


Illustration showing how wingless cylinder plane would be driven by jets of air forced out by motors in cylinders. Note, angle of tubes can be adjusted for take off or flight



ROPE WORKS SHIP'S RAT GUARD

PLACING rat guards on hawsers, a necessary precaution against an invasion of rats while a ship is tied up in port, is made less risky for seamen by a safety guard devised by a California inventor. Handled by means of a small line, as demonstrated above, it may be applied to a hawser or removed without leaving the deck of a vessel. The two hinged leaves of the guard open when the line is drawn in.

VERSATILE CUTTING TOOL USES SAFETY RAZOR BLADE

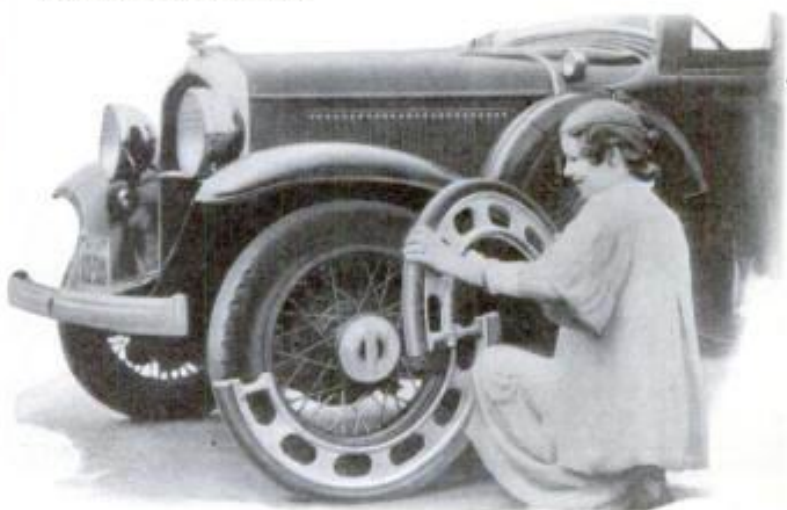
HOLDING a standard safety razor blade, a new trimming tool permits the use of both hands for heavy work. Its sturdy handles may be assembled in eighteen or more positions, for various tasks. The depth of the cut is easily regulated.



RIM PROTECTS FLAT TIRE

MOTORISTS are spared the trouble and muss of changing a flat tire by the roadside, through the use of an auxiliary rim recently placed on the market. Applied without jacking up the car or removing the tire, it provides a new riding surface and enables the driver to proceed home or to a garage, where a per-

manent repair may be effected at leisure. The rim comprises a pair of semicircular sections of aluminum alloy, encircled by a small tire of solid rubber. One of the sections is first slipped over the flange of the car wheel, and the car is driven forward a few feet, lifting the wheel from the road as shown below. The second half of the rim is then added and secured by two small bolts, completing the temporary repair.



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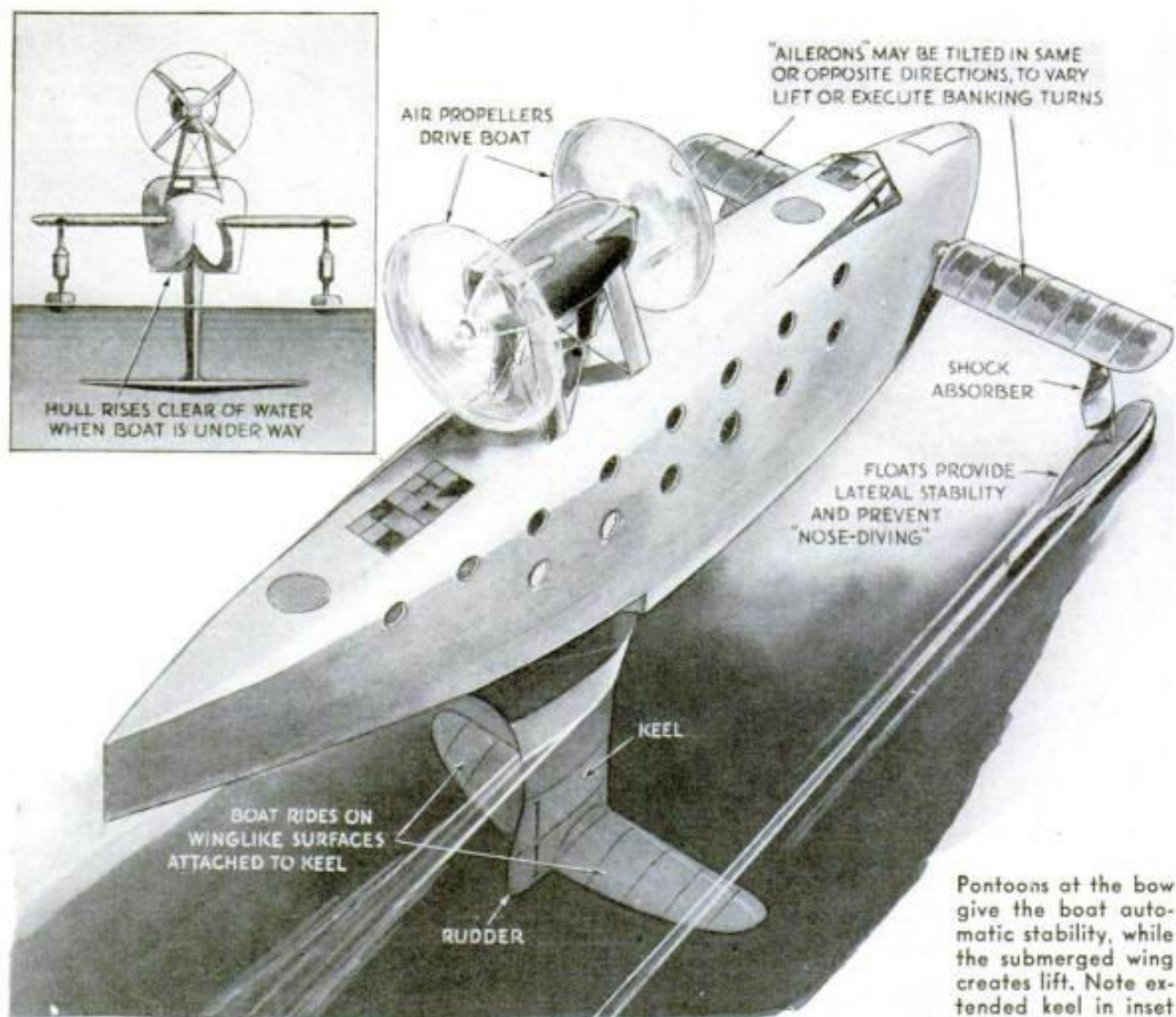


SEE PAGE 47

EDGAR
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NEW INVENTIONS • MECHANICS • MONEY MAKING IDEAS
HOME WORKSHOP PLANS AND HINTS • 350 PICTURES



Boat Rides on Underwater Wing

NOVEL PLANELIKE CRAFT SKIMS OVER THE WAVES

SKIMMING along the water at high speeds, with its hull entirely clear of the surface, a curious, airplane-type speedboat designed by a French inventor, Wsevolode Grunberg, of Paris, is supported by a specially designed central keel, supplemented by two forward pontoon floats. Plans for the novel water craft call for a hull that resembles the port-hole-studded fuselage of a giant transport plane, surmounted by a strut-supported engine whirling twin propellers, one facing toward the bow and the other toward the stern, to furnish both a pushing and a pulling force. The majority of the craft's weight is supported by a horizontal wing-shaped surface extending out at either side of the rudder, near the base of the keel. Lateral stability of the craft is obtained by the bow pontoon floats, which are connected through

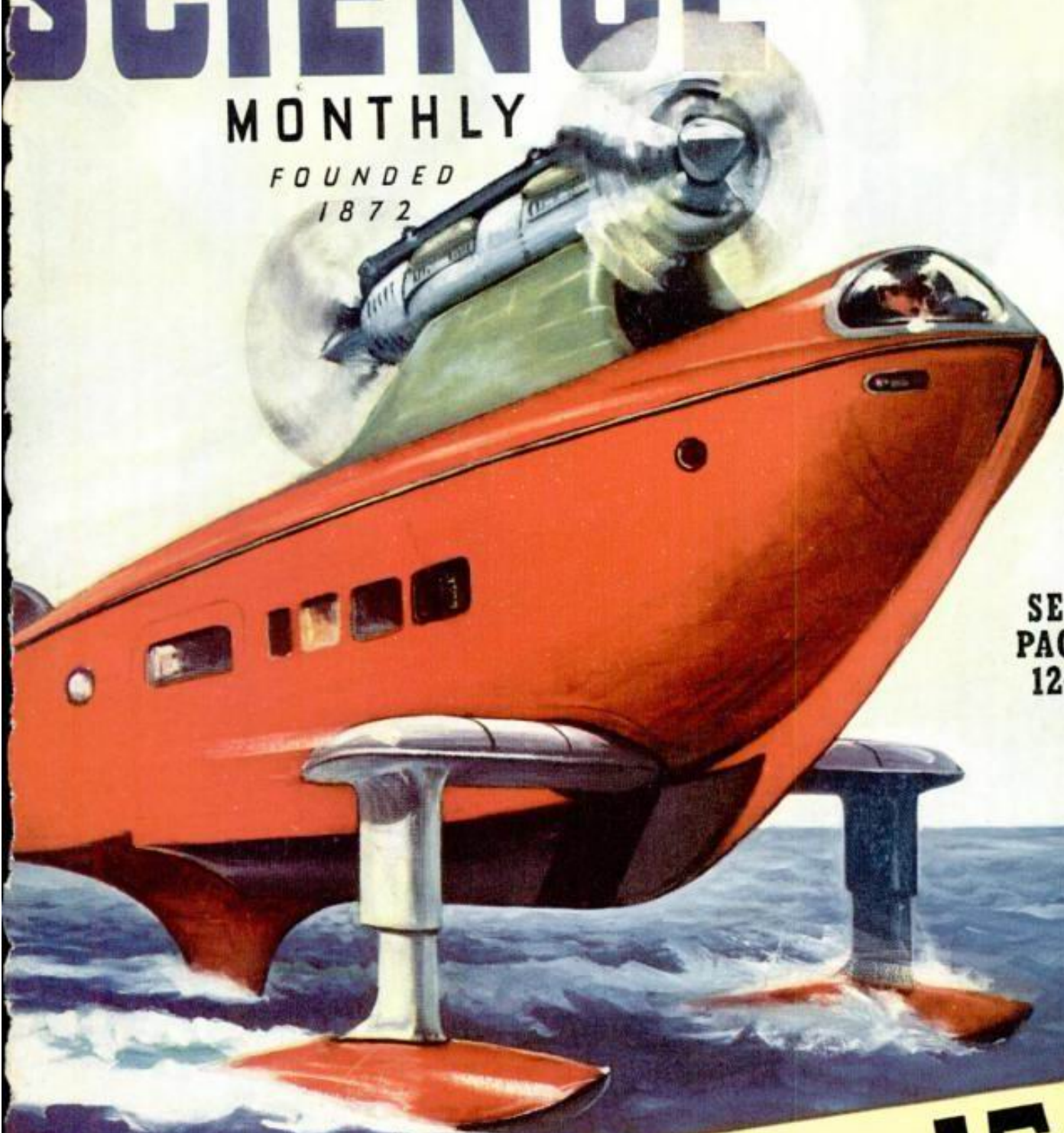
shock absorbers to adjustable horizontal members in the form of ailerons jutting out from the prow of the ship. The weight of the vessel, the inventor explains, is so distributed that the ship always has a tendency to nose-dive, or tip forward, the pontoon floats automatically keeping the craft on an even keel, since the farther they are pushed down into the water, the greater their lifting force. Thus, if a wave should cause the ship to lurch forward on its nose, the supporting force of the floats would instantly increase, while that of the horizontal section of the keel would decrease, due to the tipping action. This automatic change of forces would therefore bring the boat back to its normal position, it is claimed. The inventor points out that it would be possible to use the floats as reservoirs for fuel if desired.

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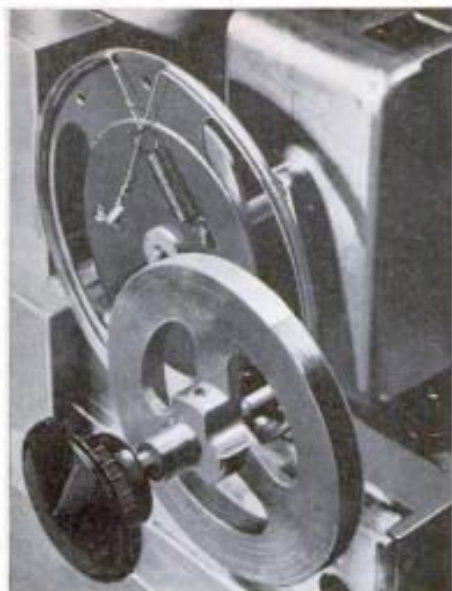
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INCORPORATING
Mechanics
AND HANDICRAFT



HEAVY FLYWHEEL SPINS RADIO TUNING DIAL

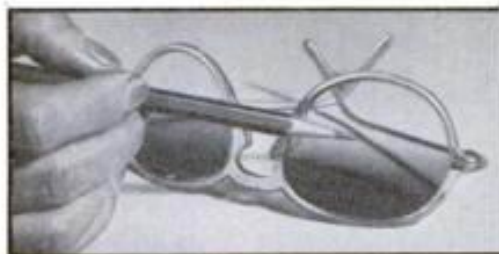
With a "lazy man's radio" of German invention, only a single twirl of the tuning knob is required to change the setting from one end of the dial to the other. A heavy flywheel attached to the shaft of the knob keeps it turning until a desired station is heard, whereupon it is stopped with the touch of a finger. In the picture above, one of the sets is dismantled to show the tuning knob and the flywheel that causes it to spin.



Cabinet of "lazy man's radio." Picture at top shows tuning knob and flywheel that spins it.

GLASSES TINTED AT TOP AND CLEAR AT BOTTOM

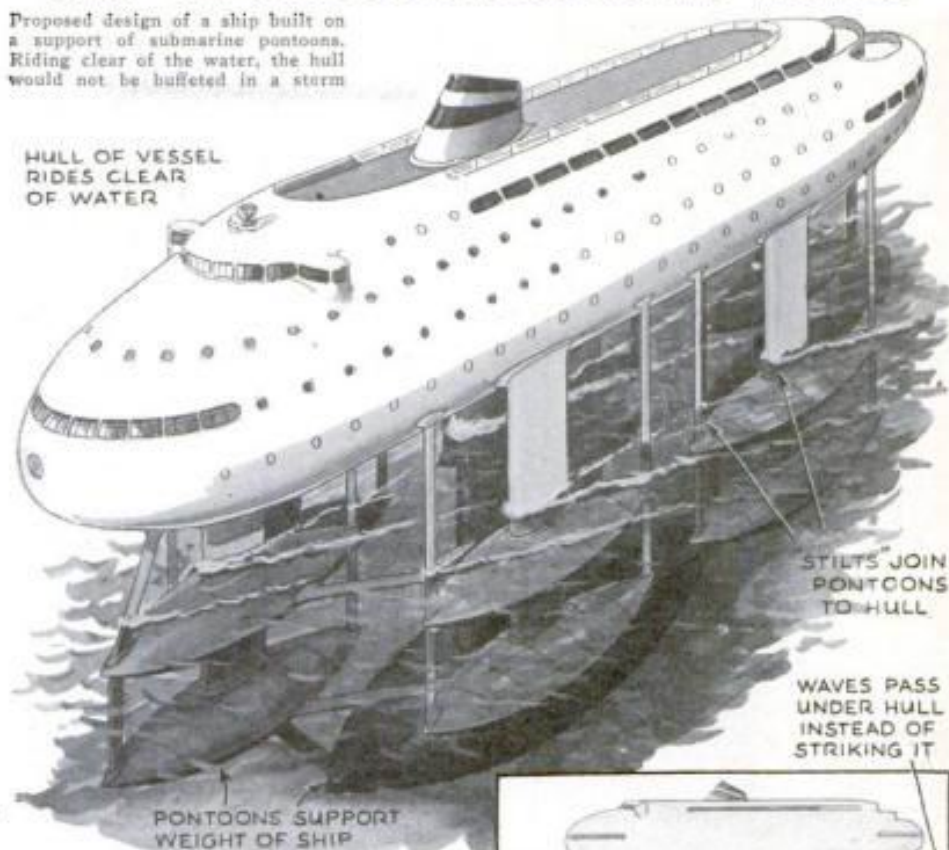
GOGGLES with graduated depth of tint are now on the market for motorists and sportsmen. Dark at the top, to shield the eyes from the glare of sunlight or automobile headlamps, the lenses shade into full transparency at the bottom. They are made by fusing a wedge-shaped section of dark glass to another of clear glass, and grinding the joined sections of glass into a single eyeglass lens.



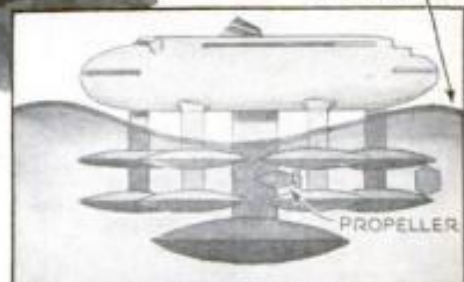
SHIP ON STILTS RIDES ABOVE WAVES

Proposed design of a ship built on a support of submarine pontoons. Riding clear of the water, the hull would not be buffeted in a storm.

HULL OF VESSEL RIDES CLEAR OF WATER



OCEAN LINERS on stilts are proposed by a Portland, Ore., inventor, to offer travelers safety and comfort at sea. His design envisages a craft supported by buoyant, submarine pontoons, in such a way that the hull itself rides clear of the water. Its elevation above the surface would be sufficient to allow heavy waves to pass beneath it without striking it, eliminating the buffeting to which most ships are subjected in bad weather. Rolling and pitching would thus be minimized. The streamline pontoons are so arranged that they rest in a calm level below the surface layer of disturbed water, and their broad, flattened upper and lower surfaces resist any sudden vertical movement. The propeller is situated nearly amidships, and the tunnel-like inclosure formed by the



BROAD, FLATTENED SURFACES OF PONTOONS CHECK ROLLING AND PITCHING BY OFFERING RESISTANCE TO ANY VERTICAL MOVEMENT. . . .

surrounding pontoons is declared to give high propulsive efficiency. The added weight of the pontoon structure would not be as great as might be imagined, it is maintained, since the elimination of heavy shocks and strains upon all parts of the ship would permit the extensive use of lightweight alloys in its construction.



Graduated-tint goggles in use. They shield a motorist's eyes against glare, while permitting a clear view of the road. At left, pencil shows how the dark section shades into clear glass.

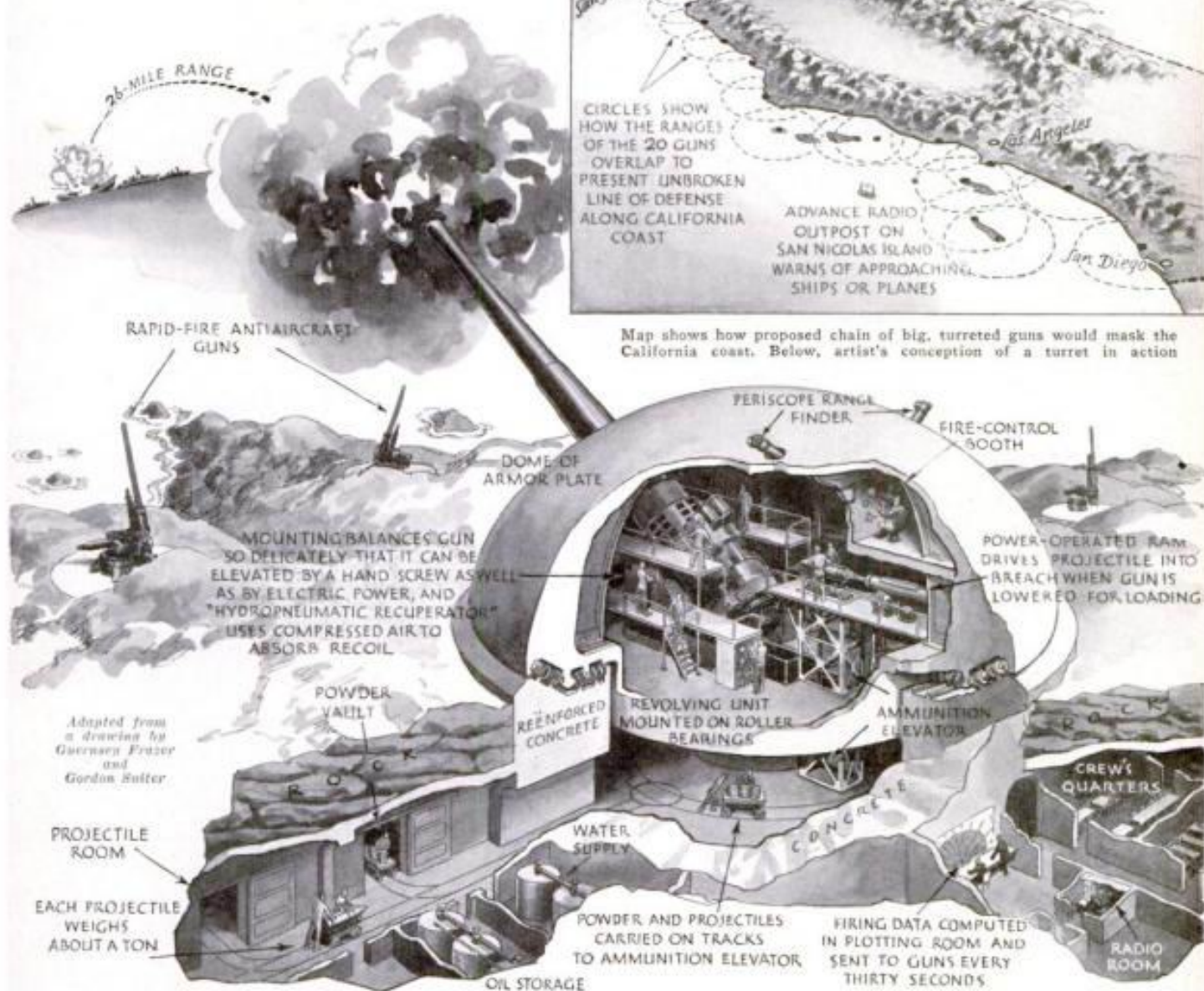


SLIDES CHANGE NEON SIGN

SALES MESSAGES may be varied with a new, changeable neon sign. When its cover glass is removed, flexible slides bearing transparent standardized legends may be inserted, as shown. If he prefers, the user may employ a special frame and fonts of letters and numbers to make up his own signs.

Chain of Forts To Guard Coast Line

*Steel-Domed, Rotating Turrets,
Guarded by Antiaircraft Batteries,
Will Form an Unbroken Line
Of Defense for 600 Miles*



Map shows how proposed chain of big, turreted guns would mask the California coast. Below, artist's conception of a turret in action

TWENTY batteries of sixteen-inch guns housed within steel and reinforced-concrete naval-type turrets will provide a continuous line of defense for the California coast from the Mexican border to San Francisco, and for the harbors at Eureka and Crescent City farther north. This plan of "perfect defense," drawn up by a California defense committee, has been presented to Secretary of War Dern and part of the scheme has been approved by the War Department.

Capable of throwing projectiles weighing nearly a ton twenty-six miles against an enemy fleet, twenty batteries, including six sunk on islands of solid rock off Southern California, would present an unbroken line of defense along the 600

miles from San Diego to the Golden Gate.

Plans give each battery two big guns, defended by four of the recently developed 4.2-inch antiaircraft guns, each of which can throw sixteen shells a minute five miles into the air. Each of these antiaircraft projectiles, exploded by a time fuse, would drive down any plane within a radius of 250 feet.

Several of the batteries, particularly those on San Miguel, Santa Cruz, Santa Catalina, and San Clemente islands, would be virtually hidden in the solid rock. Only the crown of the revolving, steel-domed turrets, would be visible. Ammunition would be stored in rocky caverns fifty feet below the surface, and lifted by electrical hoists to the guns. Automatic rammers would speed firing, while elec-

trical aiming gear would facilitate pointing and training. Fire-control officers would look out over the sea through periscopes.

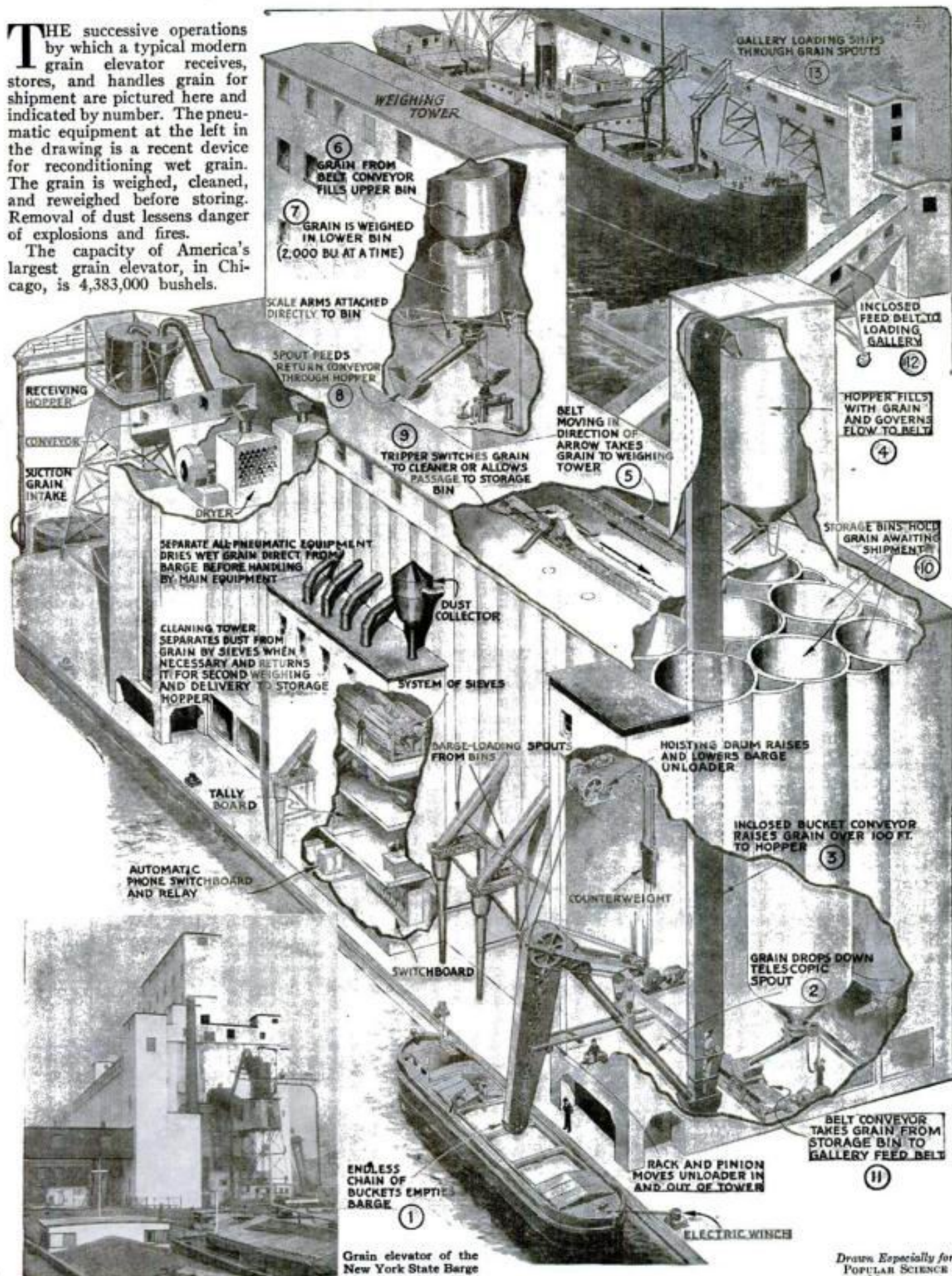
According to plans, each turret would be supported on roller bearings, and could sweep both sea and land in a complete circle. Also, each would be sealed to prevent intrusion of gas from bombs or shells. A spring sleeve on each gun would make the gun opening air-tight, while the air inside the turret and crew's quarters would be maintained at slight pressure to blow out any gas that might enter.

Each battery will be supplied with food and supplies adequate to maintain officers and crews during a six-month siege. Fifty men are believed adequate to maintain each gun during a long engagement.

Inside a Modern Grain Elevator

THE successive operations by which a typical modern grain elevator receives, stores, and handles grain for shipment are pictured here and indicated by number. The pneumatic equipment at the left in the drawing is a recent device for reconditioning wet grain. The grain is weighed, cleaned, and reweighed before storing. Removal of dust lessens danger of explosions and fires.

The capacity of America's largest grain elevator, in Chicago, is 4,383,000 bushels.



Grain elevator of the New York State Barge Canal terminal, Erie Basin, N. Y. Harbor.

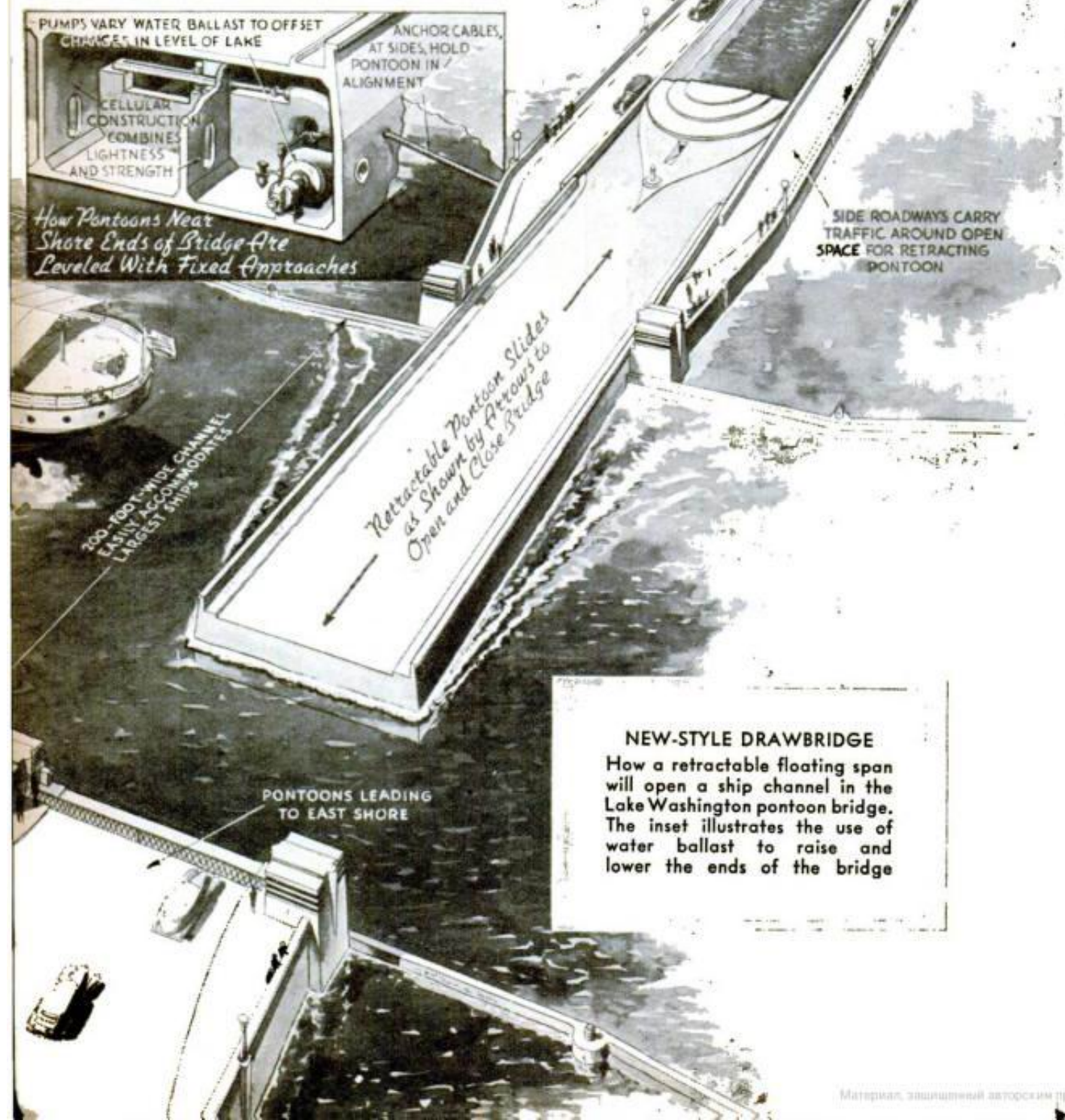
Drawn Especially for
POPULAR SCIENCE
MONTHLY
by B. G. Svelstad

World's Longest Pontoon Bridge

A GIANT mechanical mouth will stick out its tongue to close a 200-foot-wide gap at the center of the world's longest pontoon bridge. Motor traffic will then be able to cross Lake Washington, where the bridge is under construction, between Seattle, Wash., and the mainland to the east. When the tongue is withdrawn, the largest vessels can team through the opening on their way to a lock canal leading to Puget Sound and the sea.

Because of the extreme depth of the lake, and its soft muck bottom, engineers decided a floating bridge was the only practical way of spanning its 1½-mile width. Therefore the roadway will be supported by 300-foot pon-

toons of reinforced concrete for more than a mile of its total 8,700-foot length. The gap for big ships is provided by retracting one of the pontoons into an adjacent one of U-shaped design. Since the lake rises and falls within a four-foot range, pumps vary water ballast to level the pontoons near the shore ends with the fixed approaches. The bridge will eliminate a fifty-one-mile detour.



NEW-STYLE DRAWBRIDGE

How a retractable floating span will open a ship channel in the Lake Washington pontoon bridge. The inset illustrates the use of water ballast to raise and lower the ends of the bridge

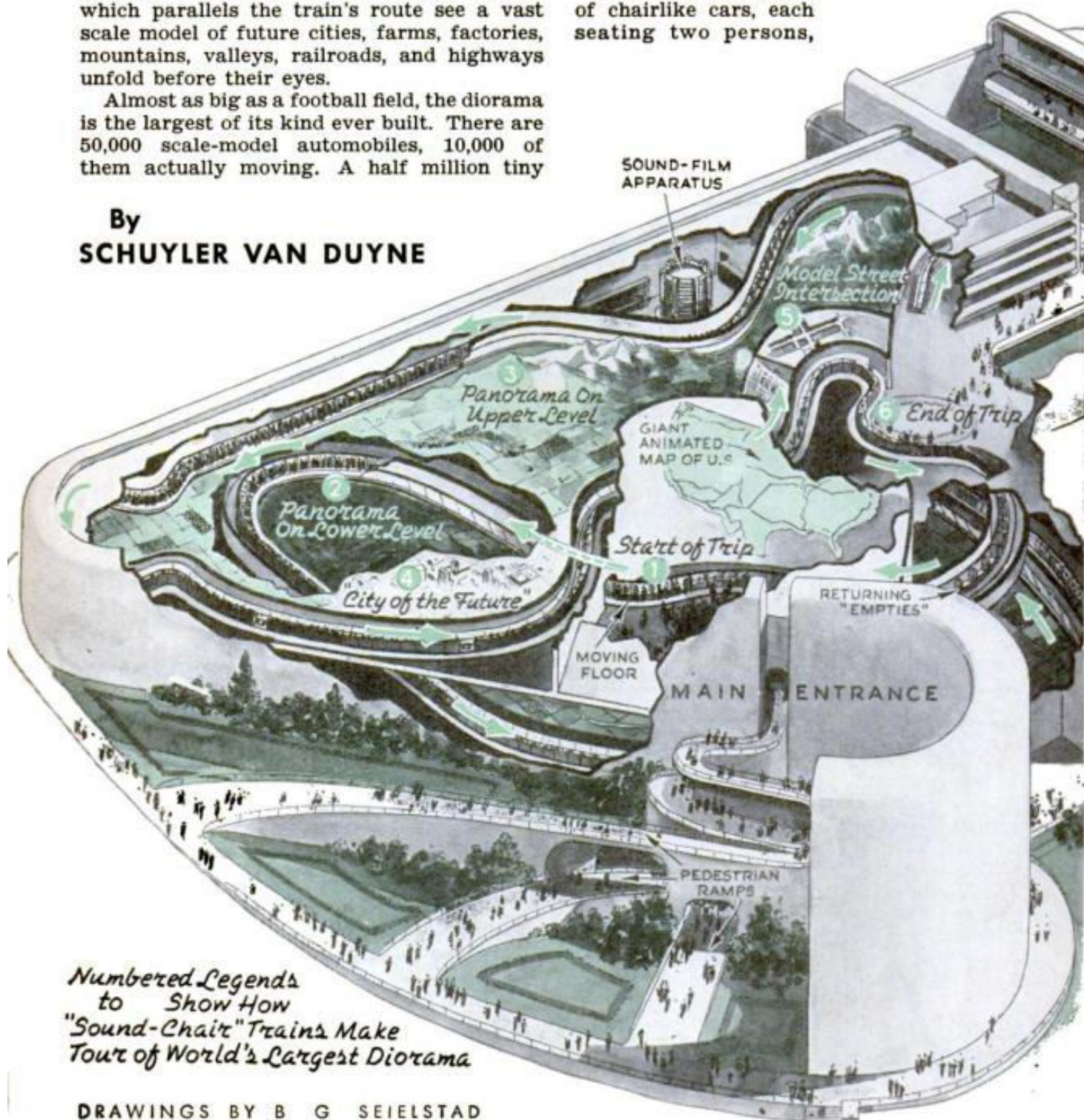
RIDING a twentieth-century, sound-equipped "magic carpet" across a miniature America of the year 1960! That is the daily experience of thousands of visitors to the General Motors exhibit at the New York World's Fair. Comfortably seated in chairs that form an endless, 300-car train, 600 passengers looking through a long window which parallels the train's route see a vast scale model of future cities, farms, factories, mountains, valleys, railroads, and highways unfold before their eyes.

Almost as big as a football field, the diorama is the largest of its kind ever built. There are 50,000 scale-model automobiles, 10,000 of them actually moving. A half million tiny

buildings comprise its many cities and villages. Snow-covered mountains are crossed, and deep ravines explored, before the spectators come to the end of the preview of what the nation's "Highways and Horizons," as the spectacle is named, may well look like twenty years from today.

As the endless chain of chairlike cars, each seating two persons,

By
SCHUYLER VAN DUYN

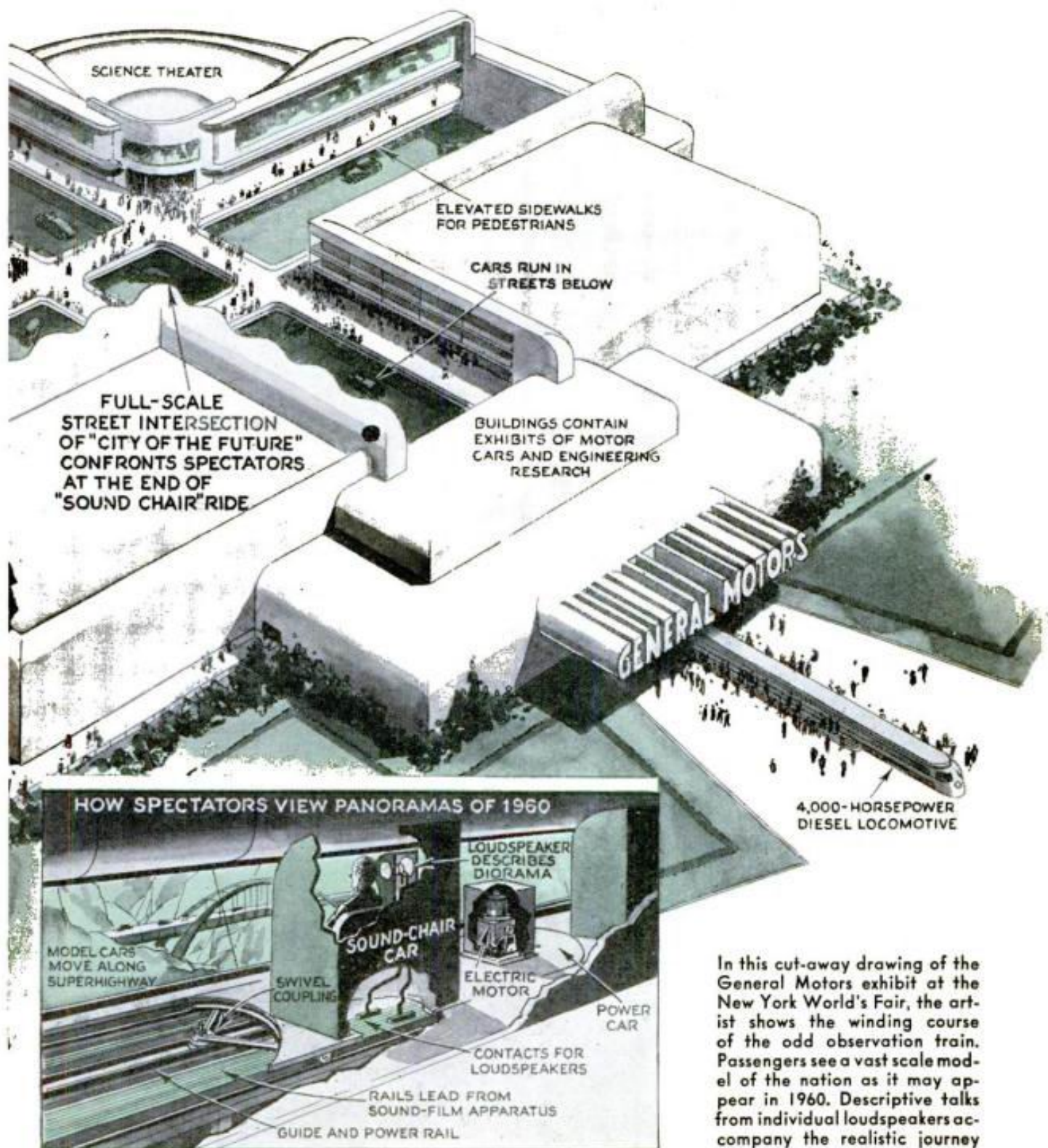


*Numbered Legends
to Show How
"Sound-Seat" Trains Make
Tour of World's Largest Diorama*

DRAWINGS BY B G SEIELSTAD

twists and winds through the air-conditioned passageway flanking the huge "futurama," loudspeakers built into the chair backs bring to the spectators a descriptive talk explaining the exhibit. To make this possible, expert

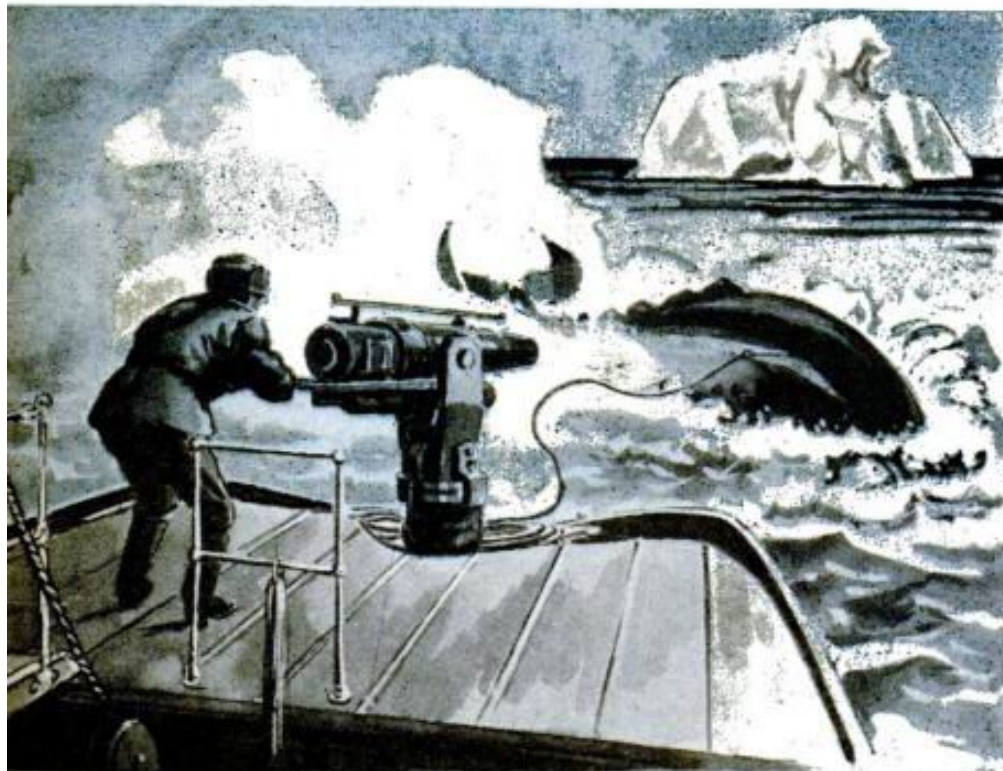
sound engineers were called in to develop and build one of the most complicated public-address systems ever devised. So sensitive is its twenty-ton sound mechanism that it had to be set in huge blocks of rubber to guard it from vibration, and virtually shut up in an



In this cut-away drawing of the General Motors exhibit at the New York World's Fair, the artist shows the winding course of the odd observation train. Passengers see a vast scale model of the nation as it may appear in 1960. Descriptive talks from individual loudspeakers accompany the realistic journey

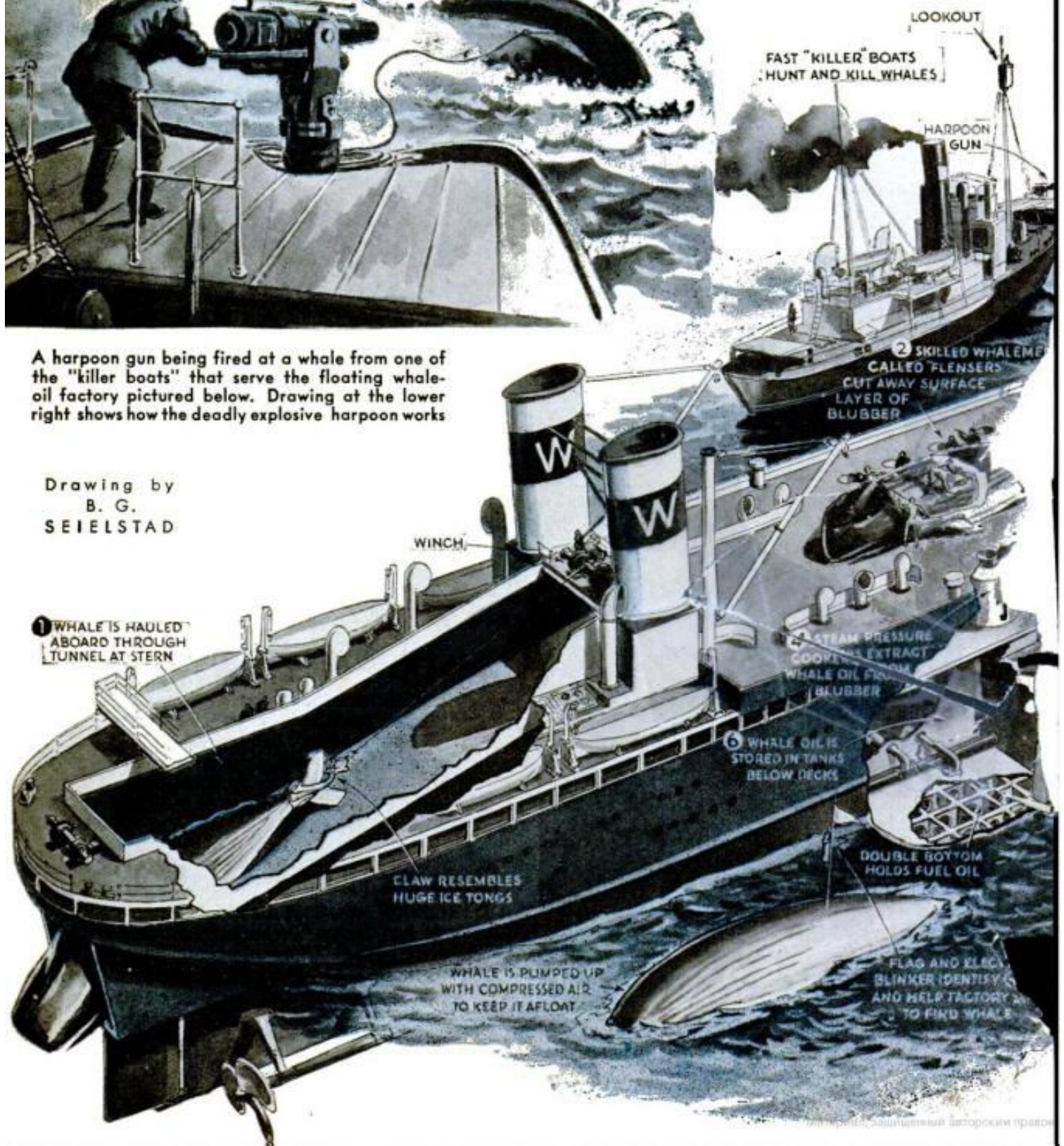
Floating Factory

**FAST "KILLER" BOATS,
BRING GREAT CHANGES**



A harpoon gun being fired at a whale from one of the "killer boats" that serve the floating whale-oil factory pictured below. Drawing at the lower right shows how the deadly explosive harpoon works

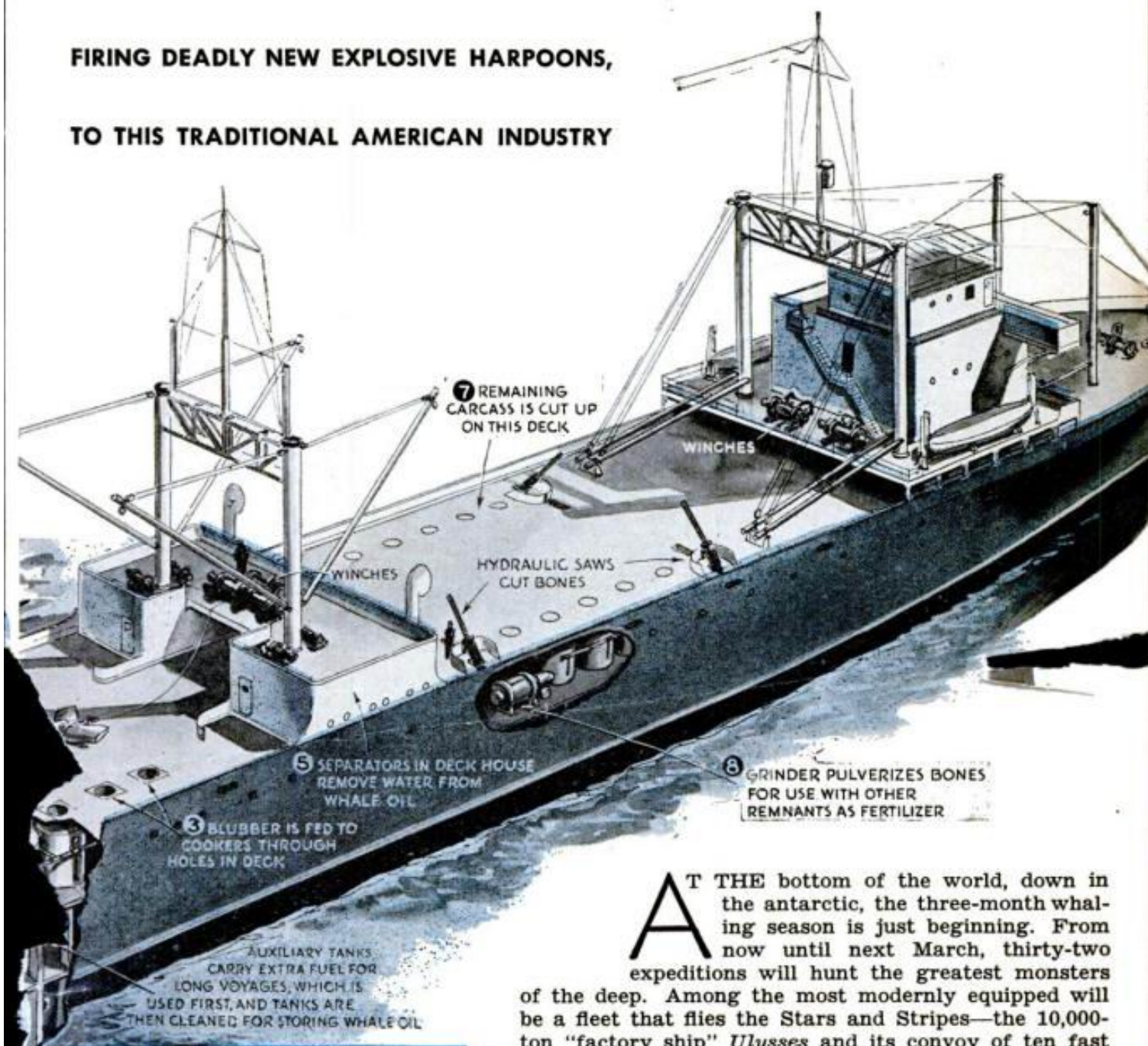
Drawing by
B. G.
SEIELSTAD



Aids Modern Whalers

FIRING DEADLY NEW EXPLOSIVE HARPOONS,

TO THIS TRADITIONAL AMERICAN INDUSTRY



AT THE bottom of the world, down in the antarctic, the three-month whaling season is just beginning. From now until next March, thirty-two expeditions will hunt the greatest monsters of the deep. Among the most modernly equipped will be a fleet that flies the Stars and Stripes—the 10,000-ton “factory ship” *Ulysses* and its convoy of ten fast 140-foot “killer” boats.

In recent years, British and Norwegian ships have held a virtually undisputed monopoly of the whaling industry, supplying millions of dollars' worth of whale oil to soap manufacturers and others who use it. Gone from the sea were the adventurous American whalers that once put out by the hundreds from centers like Nantucket and New Bedford, Mass. Then, last year, began a revival of large-scale whaling by Americans.

In April 1938 the *Ulysses*, converted from a tanker into a giant floating whale-oil factory, returned from its maiden voyage to the southern whaling grounds. It bore 9,000 tons of whale oil, valued at \$1,000,000. Fighting storms worse than tropical hurricanes, and often working in half darkness, the modern inheritors of the American whaling tradition captured more than 4,000 whales. Their prize kill, a blue whale ninety-

Plan Overland "Flying Hotels"

By

JOHN E. LODGE

FLYING hotels" with accommodations for 160 air passengers are planned for American airways, according to the recent announcement of a Connecticut firm which projects their construction. The monster land planes, whose wing span of 262 feet would make them nearly twice the size of any airplane ever built, would be used for cross-country transportation in competition with railroads. Four of the ships are scheduled to take the air by the latter part of 1930. Others are to follow.

In the accompanying drawing the artist presents his conception of such an airplane, based on the plans of its designer, Dr. William W. Christmas, a pioneer in aeronautics, who claims to have been the first man after the Wright brothers to fly a powered airplane in the United States. To give some idea of the dimensions of the proposed craft, it is said that traffic on a wide city thoroughfare could pass unhindered between its landing wheels.

THE hollow wing, measuring nine feet from top to bottom at its thickest part, will contain passenger cabins and dining saloon. Two double-deck, fuselage-shaped outriggers will contain the engines and quarters for a crew of seventeen, with room to spare for two passenger saloons. Each saloon will seat forty-two persons, while the remainder will be in cabins along the leading edge of the hollow wing. Seats in the cabin can be transformed into sleeping berths.

Sitting in the saloons or cabins of the ship will be much like occupying a seat in a hotel lounge or a Pullman train. Muffled exhausts and the remoteness of the engines will tend to prevent noise and vibration. On two open-air observation decks atop the outriggers, passengers may sit behind windshields.

Engines totaling more than 8,000 horsepower, in the interior of the plane, are planned to drive the seventy-two-ton craft at a maximum speed of 145 miles an hour. Sufficient fuel will be aboard for an eight-hour flight at this speed. The airliner will have a maximum altitude or "ceiling" of 15,000 feet.

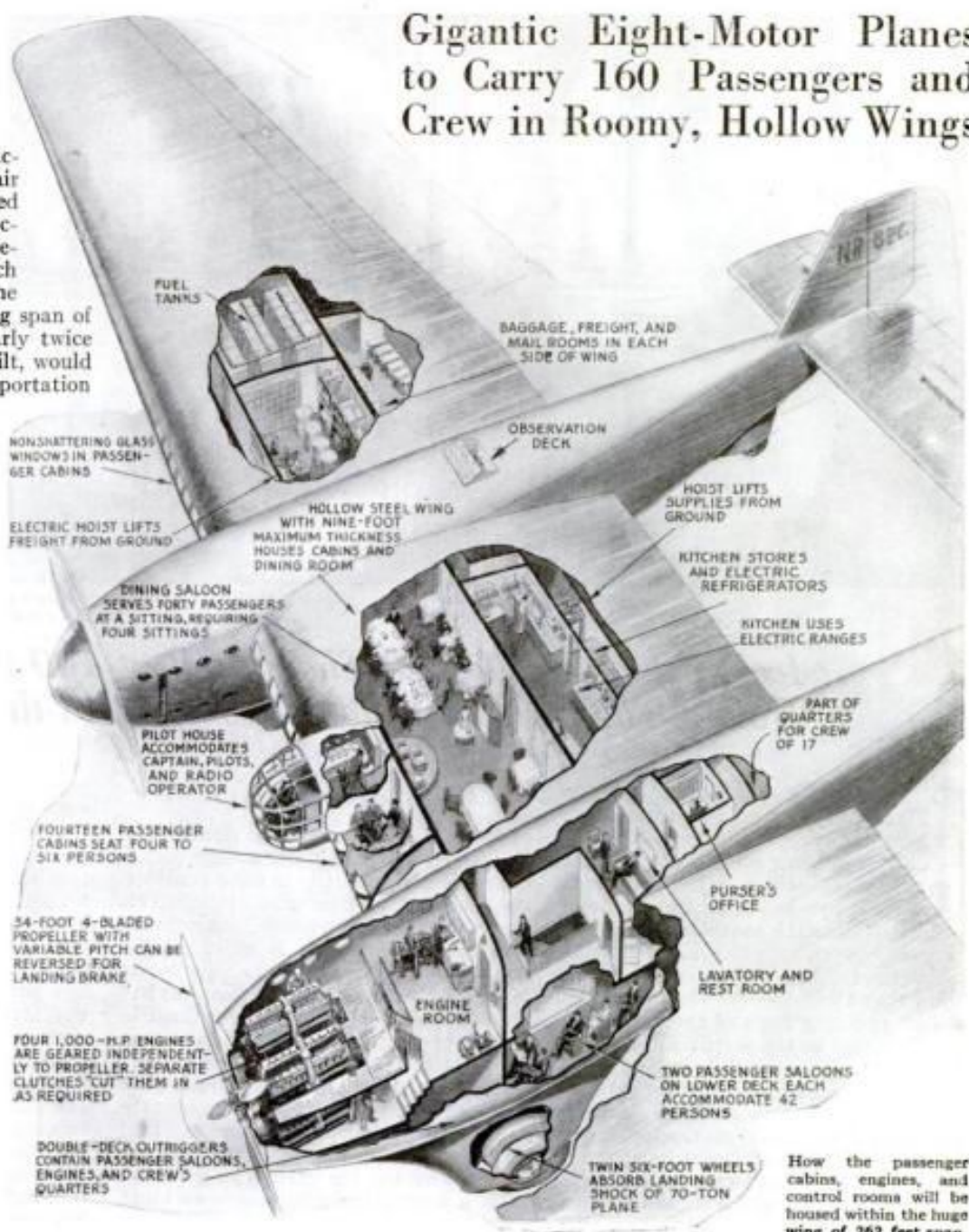
Banks of four engines will operate each of the thirty-four-foot, low-speed propellers through a novel arrangement that will permit any motor to be "cut" in or out independently of the others. For

cruising speed six of the eight engines will be used, and for short periods it is expected that as few as two of the engines will be sufficient to maintain altitude.

THE possibility of cutting out a disabled engine will facilitate easy repair in flight. All engines are to be chemically cooled at a saving of one third the weight of a system using a radiator and water for cooling. The pitch of the propellers will be adjustable in flight for most efficient operation, and the blades can be reversed to serve as a brake in landing.

Squarely in the center of the wing span will be the pilot house where the captain, pilots, and the radio operator will be on duty. There vision in all directions, including above and below, will be assured by an encircling shell made of panes of shatter-proof glass. Directly in front of

Gigantic Eight-Motor Planes to Carry 160 Passengers and Crew in Roomy, Hollow Wings

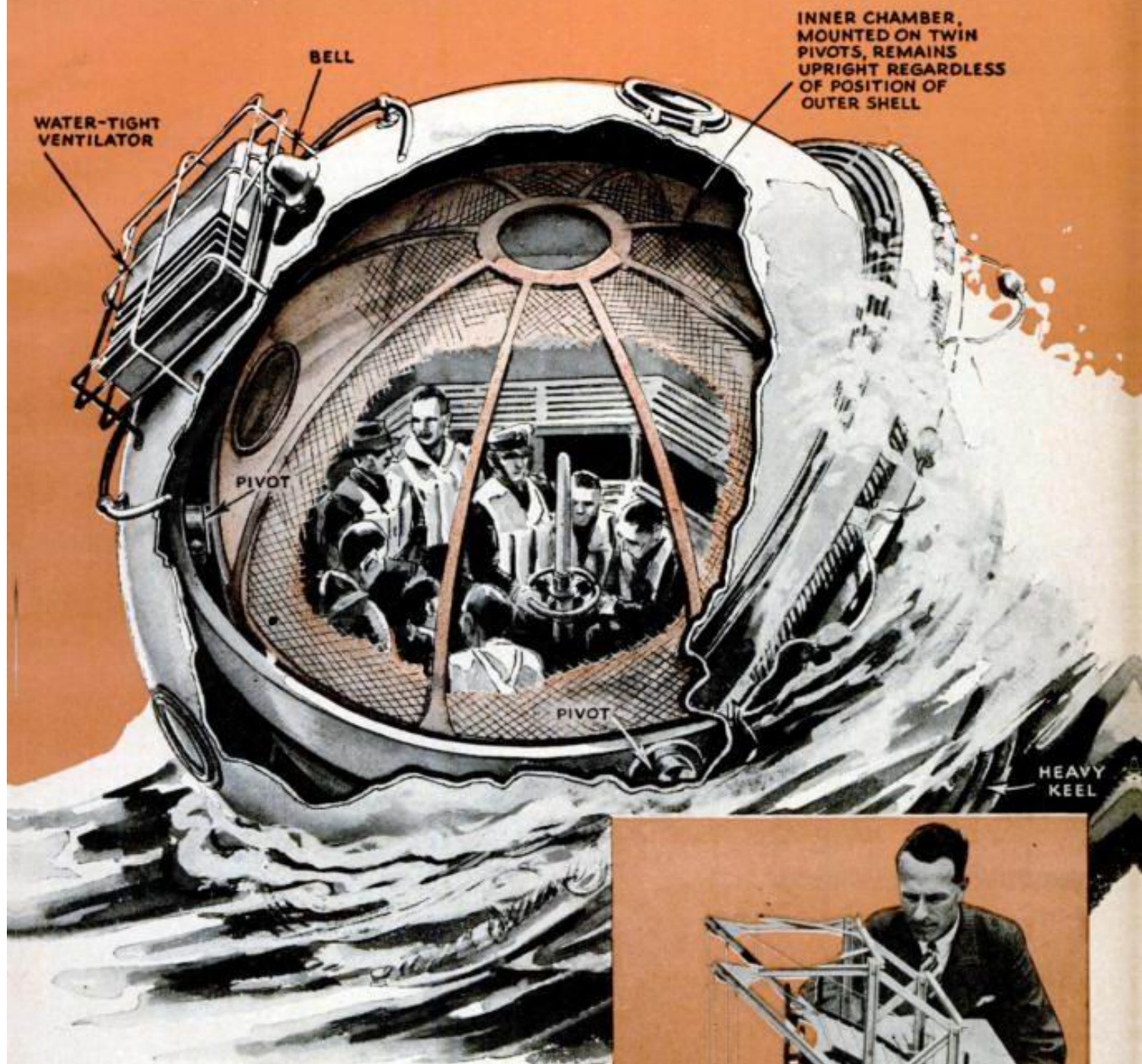


How the passenger cabins, engines, and control rooms will be housed within the huge wing of 262 feet span.

the pilots will be the controls and navigating instruments. The airliner's master and radio operator will share the rear part of the pilot house, which will be in constant communication by telephone with the engine rooms.

Electricity from engine-driven generators will operate electric stoves and refrigerators in the kitchen, electric hoists for loading freight and food supplies from the ground, and the radio telephone and radio beacon apparatus. Exhaust heat will warm the interior of the plane, through a waste-heat boiler that will circulate hot water to radiators. Heat also will be used to prevent formation of ice on wings and propellers.

Heat-treated alloy-steel tubing and plywood covering will be the construction materials. Each plane is expected to cost about \$2,000,000.



Novel Life-Saving Ball Holds Ship's Crew

TOSSING and rolling in heavy seas, a new life-saving sphere for ocean-going ships, invented by Ronald T. G. Mason, English engineer, has an inner passenger-carrying globe mounted on twin pivots that allow it to remain upright regardless of the movement of the outer shell. Fitted with a radio, electric lights, emergency food supplies, and a water-tight ventilating system, a life-saving ball only twelve feet in diameter could safely accommodate the entire crew of a small cargo steamer, it is claimed. On shipboard, the sphere would be suspended from a steel launching rig reached from deck level by a sloping ramp.



Ronald T. G. Mason, British inventor, with a model of his sea-rescue sphere and its launching rigging



In naval battles of the future, great warships may be destroyed by flying torpedoes, powered by built-in motors and guided straight at their targets by radio control. These could also be used on land

War

NEW TINY WEAPONS FOR LAND, SEA, AND SKY MAY REVOLUTIONIZE BATTLE TACTICS

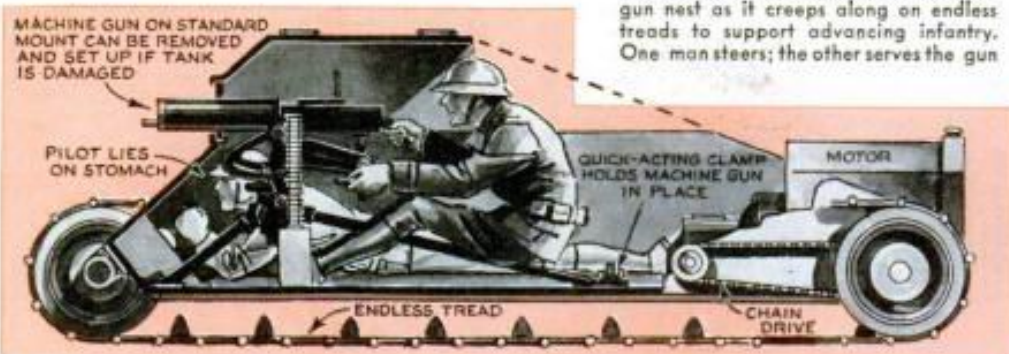
maneuvered like a glider by its lone pilot, who would aim the missile at an objective and then parachute to safety. Outstanding among new machines designed for the Navy is a one-man, electrically powered submarine that could be lowered from a battleship or cruiser. Carrying its lone torpedo close to an enemy ship, it would fire at a range short enough to insure a direct hit in a vital spot. In all these new war weapons, the trend appears to be away from ponderous, vulnerable units and toward small, deadly machines which depend for their success on the courage and initiative of one or two operators—giving new speed and striking power to the individual fighter.

Many military experts, after studying the performance of mammoth machines in the "test-tube" wars of Ethiopia, China, and Spain, believe that these Goliaths of battle may meet their match in the mechanical Davids now being perfected by the inventors.

PROFITING by the lessons of recent foreign wars, in which gigantic tanks, huge bombing planes, and other ponderous fighting machines failed to outmode standard battle tactics (P.S.M., Jan. '38, p. 25), American inventors are turning toward smaller, more accurately controlled war weapons to bolster our military and naval strength. To supplement the operations of infantry, a speedy land fighting unit has been developed in the form of a mobile, armored machine-gun nest, running on a chain-driven endless tread, manned by one gunner and one pilot, and mounting a machine gun that is removable for stationary use on the ground. Also for Army use is a lightweight flying tank, designed to speed across enemy lines at 200 miles an hour, drop to the ground, shed its detachable wings, and advance as a land unit mounting one machine gun in front and another in a central telescoping turret. The effec-

tiveness of aerial bombardment, it is expected, will be increased by a radio-controlled flying torpedo now being given flight tests. This unit, powered by a built-in motor and pusher-type propeller, is guided straight for its target by radio control from an accompanying plane or from a ground station. Similar to this is a winged bomb that could be launched from the undercarriage of a multimotored plane and

Two soldiers man this mobile machine-gun nest as it creeps along on endless treads to support advancing infantry. One man steers; the other serves the gun



Machines Go Midget

Winged tanks, landing behind enemy lines, would shed their wings and advance on wheels. Each mounts two machine guns, one in the telescoping turret



Steered like gliders, winged bombs are aimed directly at their objective by lone pilots who then bail out with their parachutes

A one-man submarine, armed with a single torpedo, is designed to be carried on a battleship. Lowered into the water, it could maneuver close to a hostile vessel and discharge its deadly missile, making sure of an effective hit in a vital spot

Illustrations by
B. G. SEIELSTAD



AT THE PERISCOPE. In the control room (see A in drawing) the commander, in left background, uses the "eye" of the submarine while aides direct the craft's movements



TORPEDO ROOM. Here (B in drawing) the submarine keeps its dreaded weapons. With the aid of steel cables, a torpedo is hauled to the slides and thrust home in the tube to wait for the target to be brought into line



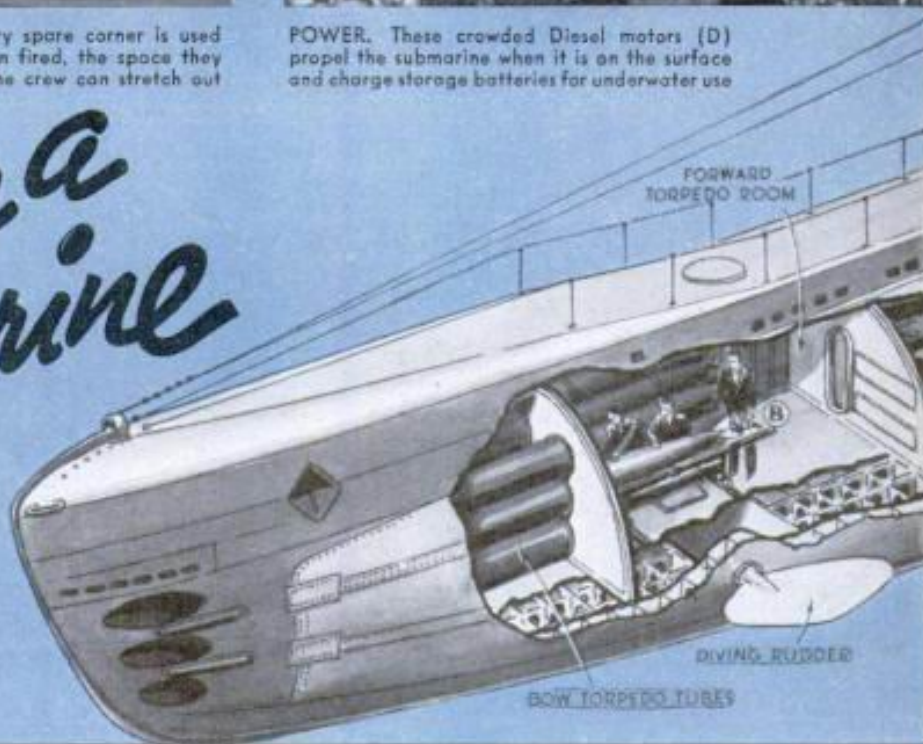
NIGHTTIME. For sleeping quarters (C), every spare corner is used for a bunk. When the torpedoes have all been fired, the space they occupied provides some extra room in which the crew can stretch out



POWER. These crowded Diesel motors (D) propel the submarine when it is on the surface and charge storage batteries for underwater use

Life on a Submarine

Forty-eight men live aboard a small submarine like the one at the right. Typical quarters are shown in the accompanying photographs, made by special permission on a British undersea craft

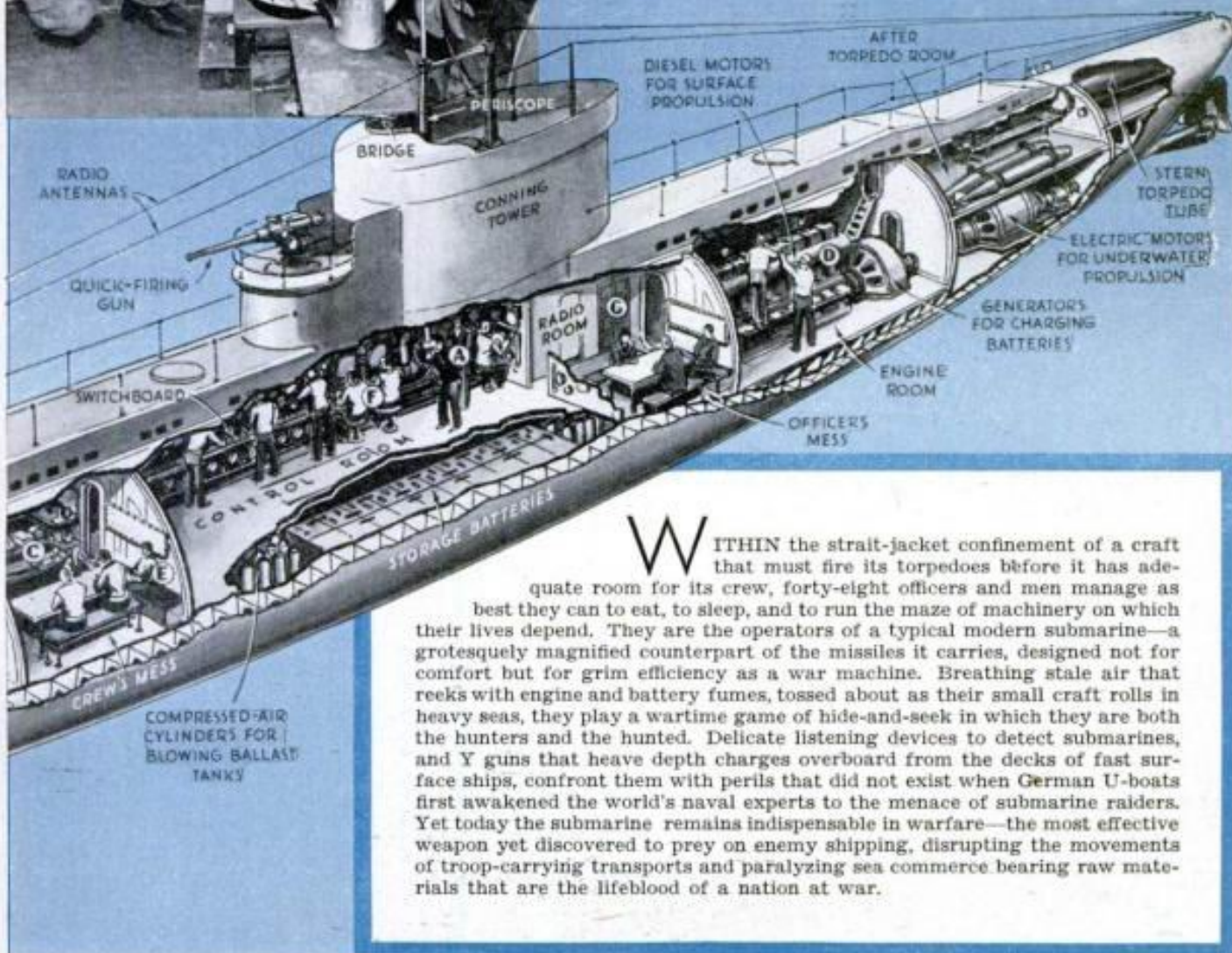
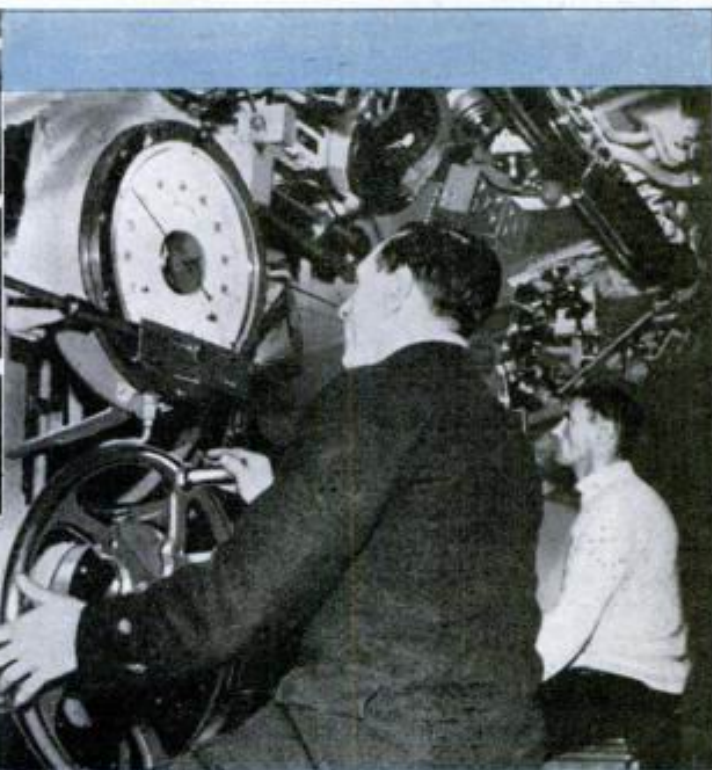




MEALTIME. With bunks folded back out of the way, the crew's quarters become a mess room. The officers' quarters (E) serve similarly for both eating and sleeping.



DEPTH CONTROL. These men are operating the wheels and levers (F) that move the diving rudders to send the ship up or down, or to keep it on an even keel. The large dial shows how many feet the craft is beneath the surface. At the left is the tiny galley (G) with its electric stove.



WITHIN the strait-jacket confinement of a craft that must fire its torpedoes before it has adequate room for its crew, forty-eight officers and men manage as best they can to eat, to sleep, and to run the maze of machinery on which their lives depend. They are the operators of a typical modern submarine—a grotesquely magnified counterpart of the missiles it carries, designed not for comfort but for grim efficiency as a war machine. Breathing stale air that reeks with engine and battery fumes, tossed about as their small craft rolls in heavy seas, they play a wartime game of hide-and-seek in which they are both the hunters and the hunted. Delicate listening devices to detect submarines, and Y guns that heave depth charges overboard from the decks of fast surface ships, confront them with perils that did not exist when German U-boats first awakened the world's naval experts to the menace of submarine raiders. Yet today the submarine remains indispensable in warfare—the most effective weapon yet discovered to prey on enemy shipping, disrupting the movements of troop-carrying transports and paralyzing sea commerce bearing raw materials that are the lifeblood of a nation at war.

Plan of the proposed "artificial spa" that will give city dwellers the opportunity to enjoy the advantages of all climates and health resorts with little trouble or expense. In the central area, visitors can swim or bask in artificial sunlight on a beach of sterilized sand, while booths surrounding the main hall offer medicinal baths, mineral waters, and various therapeutic treatments

Drawing by
B. G. SEIELSTAD

MOVIE
THEATER

GYMNASIUM

HEALTH BATHS OF EVERY KIND
INCLUDE SPECIAL WATERS, VAPOR,
HOT AIR, LIGHT, AND ELECTRICITY

AIR CONDITIONERS
MAINTAIN ARTIFICIAL
CLIMATE

ENTRANCE
LOBBY

GLASS DOME
ADMITS DAYLIGHT

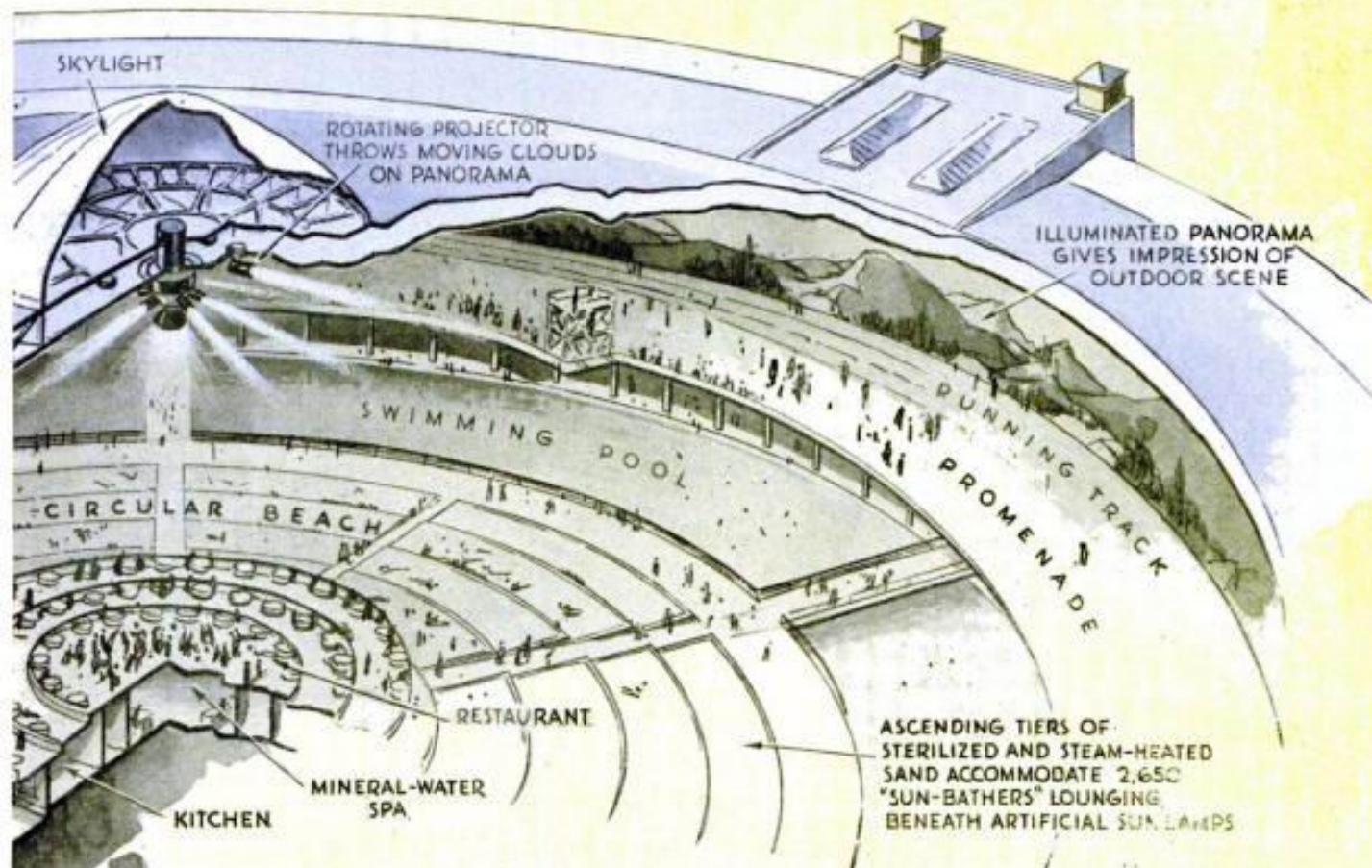
ARC LAMPS
SUPPLEMENT
ILLUMINATION
OF SAND BEACHES
AT NIGHT

TWO CIRCULAR ROWS OF
ULTRA-VIOLET LAMPS
PROVIDE ARTIFICIAL
SUNLIGHT DAY AND NIGHT

SWIMMING
POOL

DRESSING
ROOMS AND
LOCKERS

FILTERING PLANT CLEANSSES WATER
FOR SWIMMING POOL AND BATHS



Any Climate You Want

ALL THE WORLD'S HEALTH RESORTS PUT UNDER ONE ROOF

CURATIVE baths of the world's most famous spas, mineral waters from celebrated springs, and artificial climates to match seashore and mountains are brought together in a monster "artificial spa" designed by Dr. I. Goldmerstein of Paris, France, and Prof. Karl Stodieck of Berlin, Germany. Their plan would place all the benefits of expensive health resorts within reach of the inhabitants of large cities, they told a recent meeting of a scientific society in New York.

The project calls for a circular, glass-domed structure enclosing six and a half acres, to be erected at a cost of \$6,000,000 in the heart of the city, and to be open to the public for two periods daily. Paying a small admission fee and trading his street clothes for a bathing suit, a visitor finds himself in a vast amphitheater illuminated day and night by artificial sun lamps. A few steps across a sandy promenade bring him to the edge of a ring-shaped swimming pool nearly a quarter mile in circumference. After a swim, he may lounge on the sterilized, steam-heated sand

of a circular terraced island at the center of the pool, chatting with friends or enjoying the music of an orchestra while he basks under the ultra-violet lamps. A huge scenic panorama encircling the amphitheater, artfully lighted and painted with moving clouds by a revolving projector, completes his illusion of an outdoor setting. If the feeling of a wet bathing suit detracts from his pleasure, "hot box" compartments and ingenious presses dry him and his suit almost instantly.

Booths surrounding this main hall offer the visitor the additional benefits, at charges depending upon the treatment, of medicinal baths of every description—with mineral waters, hot air, vapor, therapeutic lamps, and X-ray treatments. Air-conditioning magic brings him the mellow climate of Florida or the dry air of Arizona and New Mexico, while he sips bottled Carlsbad water from Czechoslovakia, Vichy water from France, Saratoga Springs water from New York State, or sulphur waters from Virginia.

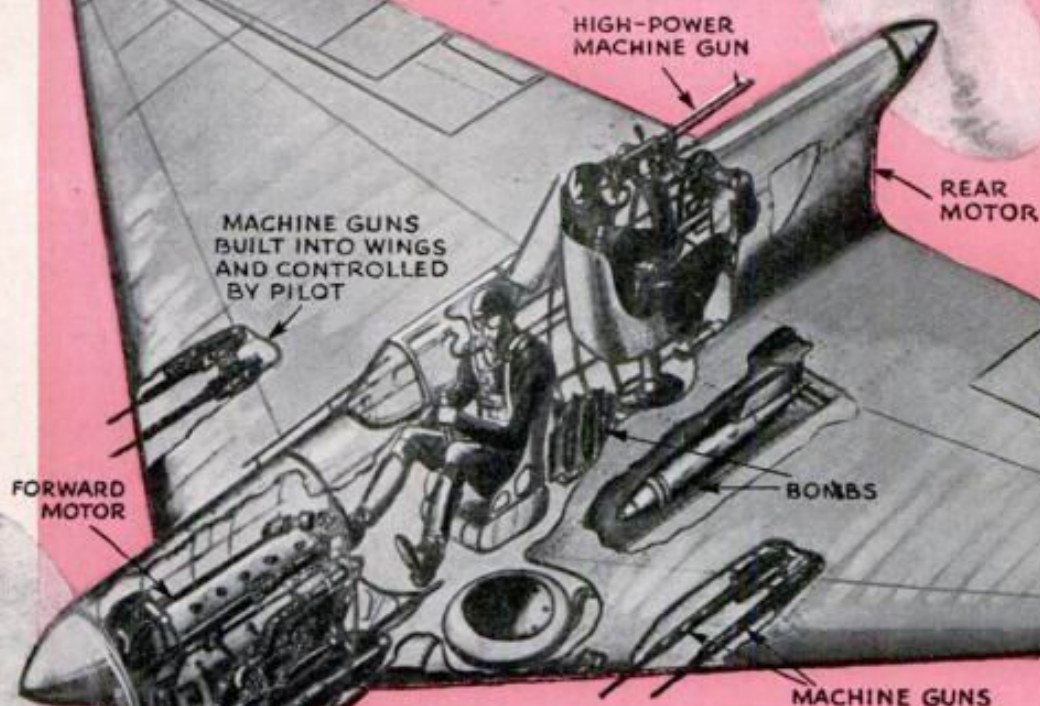
Additional attractions include five gymnasiums, a movie theater, more

than a mile of walks along which to stroll, and a running track for those more athletically inclined, as well as sporting matches and other special diversions.

A maze of machinery behind the scenes caters to the needs of the thousands who flock to the health and recreation center. No sooner does the visitor doff his street attire than his linen is whisked away by an automatic aerial conveyor—to be returned to him freshly washed and ironed, from a subterranean laundry, when he is ready to depart. Sand travels back and forth, by way of an electric car and hoist, between the beaches and a sterilizer capable of disinfecting several freight-car loads a day with superheated steam at 300 degrees.

To overcome the disadvantage of hanging the quartz sun lamps at a great height, special chromium-plated reflectors multiply the effective illumination fivefold. A "Schwedler dome," an advanced architectural design of parabolic shape and great strength, solves the problem of providing a roof 600 feet in diameter and free from central supporting pillars.

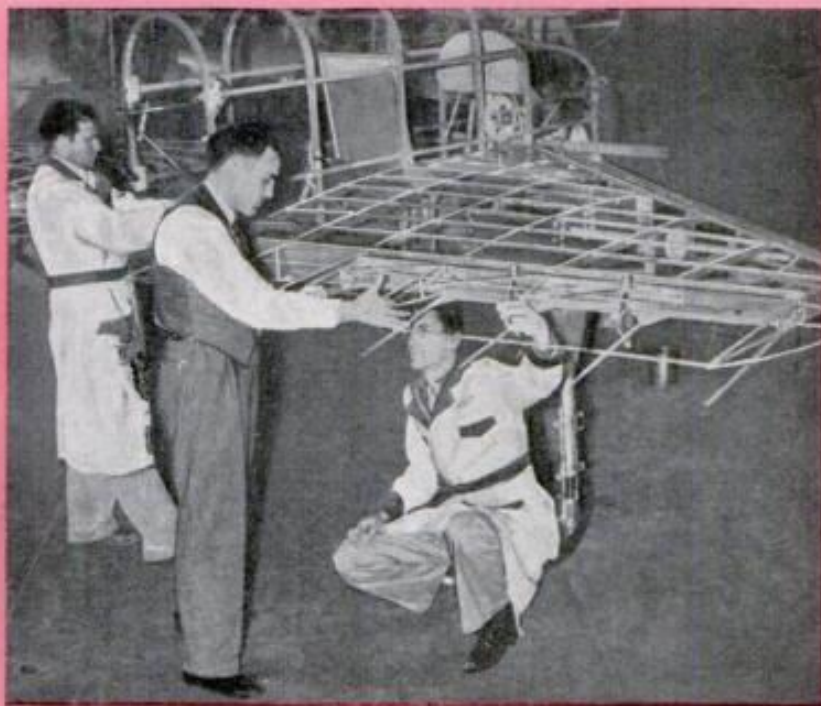
How the flying wing would be outfitted with machine guns and demolition bombs



Tailless Fighting Plane

FOLLOWING the plans of their aeronautics instructor, John D. McKellar, nearly 150 students of the California State Polytechnic School are building a new kind of tailless airplane. The radical McKellar design calls for a "flying wing" with the

fuselage inside, and propellers at both front and rear, making the strange machine a combination tractor-and-pusher type. His system of controls includes double flaps that open like the leaves of a door hinge. These flaps are pivoted horizontally near the trailing edge of the wing. When completed, the lightweight craft is expected to weigh less than 1,500 pounds. If it flies successfully, the same design may be used for a ten-ton military plane carrying bombs and a machine-gun turret. A cut-away sketch of the proposed military plane is reproduced above.

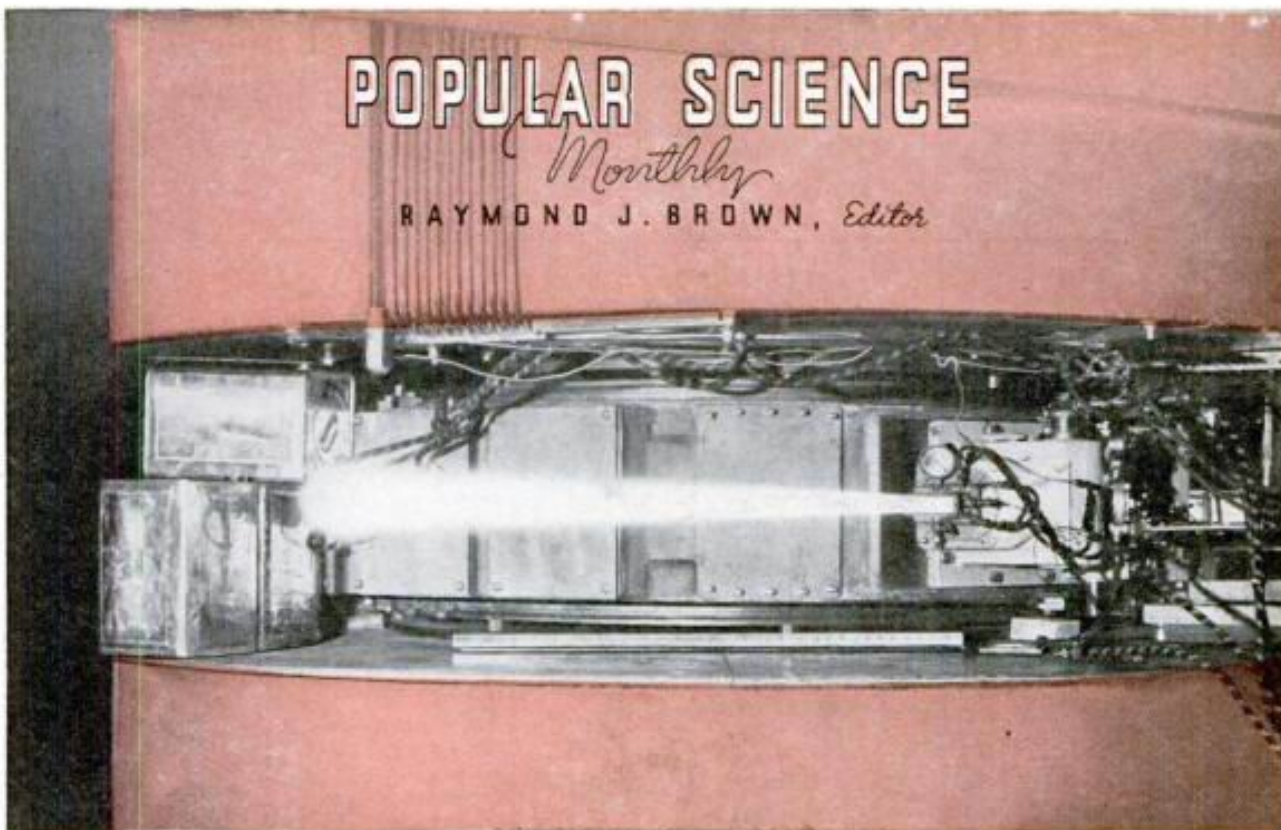


John D. McKellar (coatless) checks on his double-flap wing control

POPULAR SCIENCE

Monthly

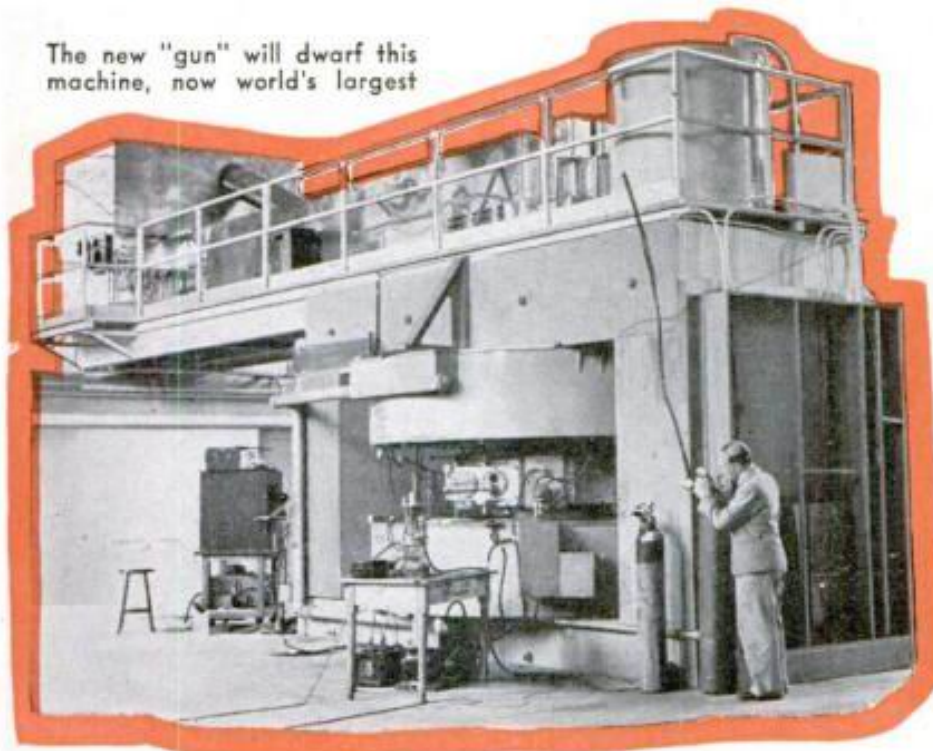
RAYMOND J. BROWN, *Editor*



Deadly blue rays streaming from the muzzle of the 200-ton cyclotron at the University of California

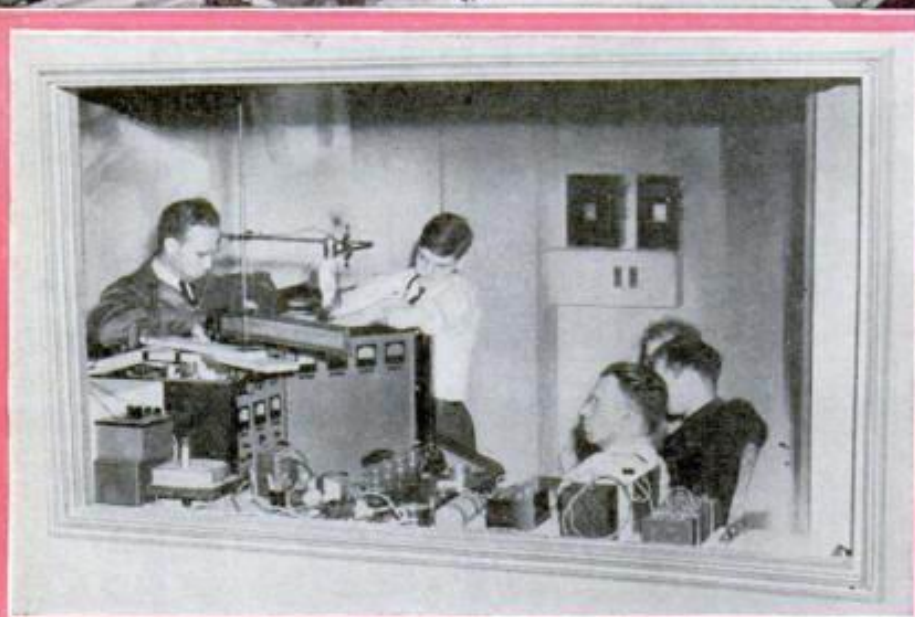
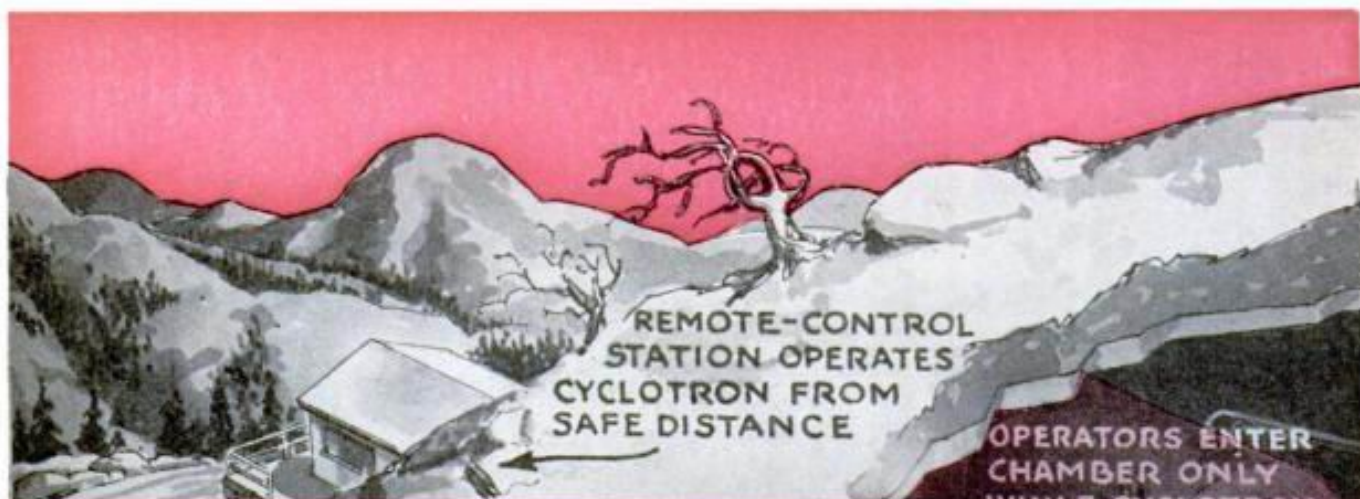
GIANT ATOM GUN TO HELP FIGHT DISEASE

The new "gun" will dwarf this machine, now world's largest



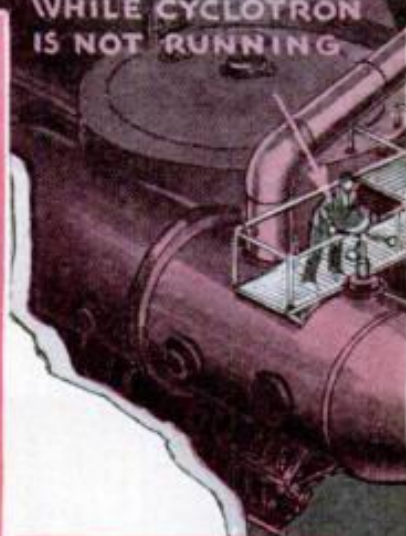
STREAMING fanwise from between the poles of the world's largest magnet, dazzling blue rays, packed with more energy than all the radium ever mined, soon may pour out of a colossal electric "machine gun" so powerful that it must be located in an isolated spot and operated by remote control.

Completely surrounded by tanks of water and buried in a hillside to guard against stray radiations, the giant "cyclotron" would be almost as large as an ordinary five-room house. Its weird blue radiations would be focused upon a target placed in a vacuum chamber, and its tremendous energy used to produce amazing,



From the control room of the present "atom gun," scientists can watch the operation of the huge machine while shielded from its radiations

OPERATORS ENTER
CHAMBER ONLY
WHILE CYCLOTRON
IS NOT RUNNING



- 1 Generator supplies power at high frequency and voltage.
- 2 Copper pipes shield transmission cables to cyclotron.
- 3 Cylinders contain tuning apparatus.
- 4 Electric power energizes D-shaped electrodes alternately.
- 5 Power also heats tungsten filament.
- 6 Hydrogen atoms, piped to tip of filament, receive electric charge.
- 7 Timed "kicks" from electrodes propel charged hydrogen atoms in spiral path.
- 8 Charged deflector plate guides stream of atoms to outlet.
- 9 100,000,000-volt particles bombard material in chamber.

miraculous changes in ordinary substances like table salt and lead.

Only its cost of \$750,000—the price of three bombing planes—is delaying its construction. By the time these words are in print, the huge generator may be taking shape at the University of California. Plans were being drawn even as its proponent received word, late last November, that he had been awarded the Nobel prize for development of the decade's most revolutionary instrument in atomic research.

Ten years ago the cyclotron was but a fantastic scheme in the mind of a young professor at the University of California. Like others, Dr. E. O. Lawrence had toyed with the idea of smashing the atom by hurling a stream of minute bullets at it. He knew that radium, in its strange, centuries-long process of disintegration, hurls out positively charged particles with peculiar powers. Under their bombardment, atoms broke down and substances underwent remarkable transformations. Now, if he could speed up the process by generating billions of such particles, shooting them at terrific speed, the alchemist's dream of transmuting base metals into gold might be realized.

Some experimenters had tried it already, firing smaller-than-atom particles by huge electric discharges of 5,000,000 to 10,000,000 volts. But these electric machine guns could not be controlled—they flared thunderously for an instant, leaving behind a tangle of wrecked,

Artist's conception of Dr. Lawrence's proposed \$750,000 cyclotron. Buried in the side of a hill, it would be run by remote control

CYCLOTRON OPERATES IN UNDERGROUND CHAMBER AS LARGE AS A HOUSE

GIANT ELECTROMAGNET MEASURES 34 FEET LONG AND 25 FEET HIGH

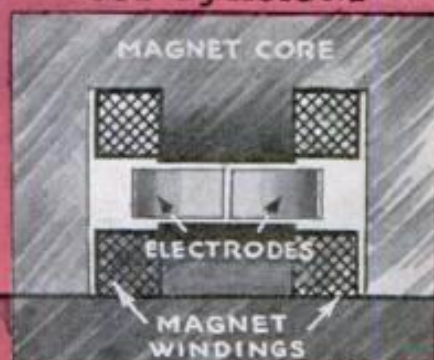
WATER TANKS HELP PREVENT ESCAPE OF STRAY RAYS

TANK OF PARAFFIN SERVES AS BACKSTOP TO CHECK DEADLY BEAM

THIS BRILLIANT BEAM, FATAL TO ANYONE IN ITS PATH, WOULD BE 75 FEET LONG IF UNOBSTRUCTED

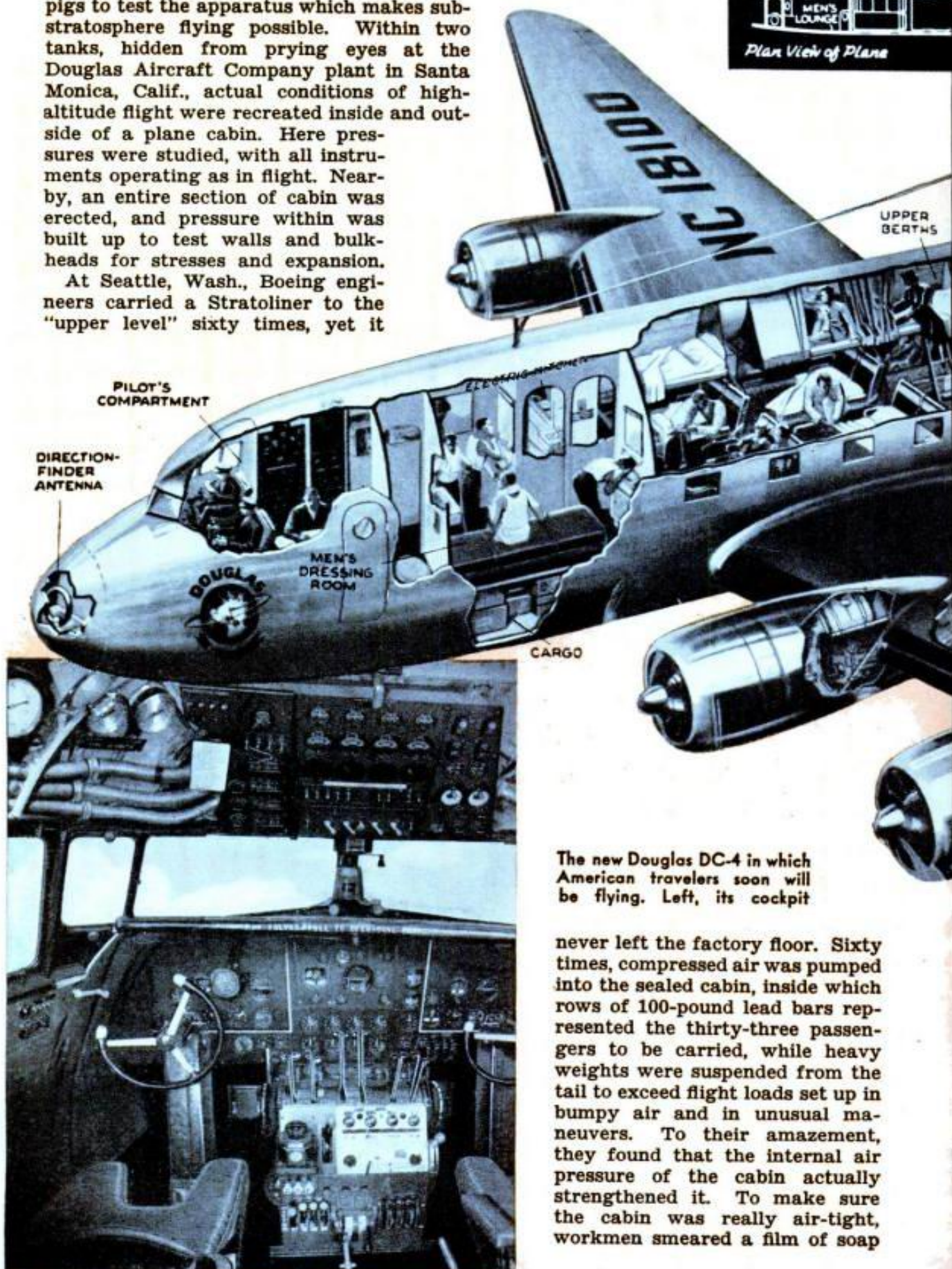
Drawing by
B. G. SEIELSTAD

Comparative size of man and Cyclotron



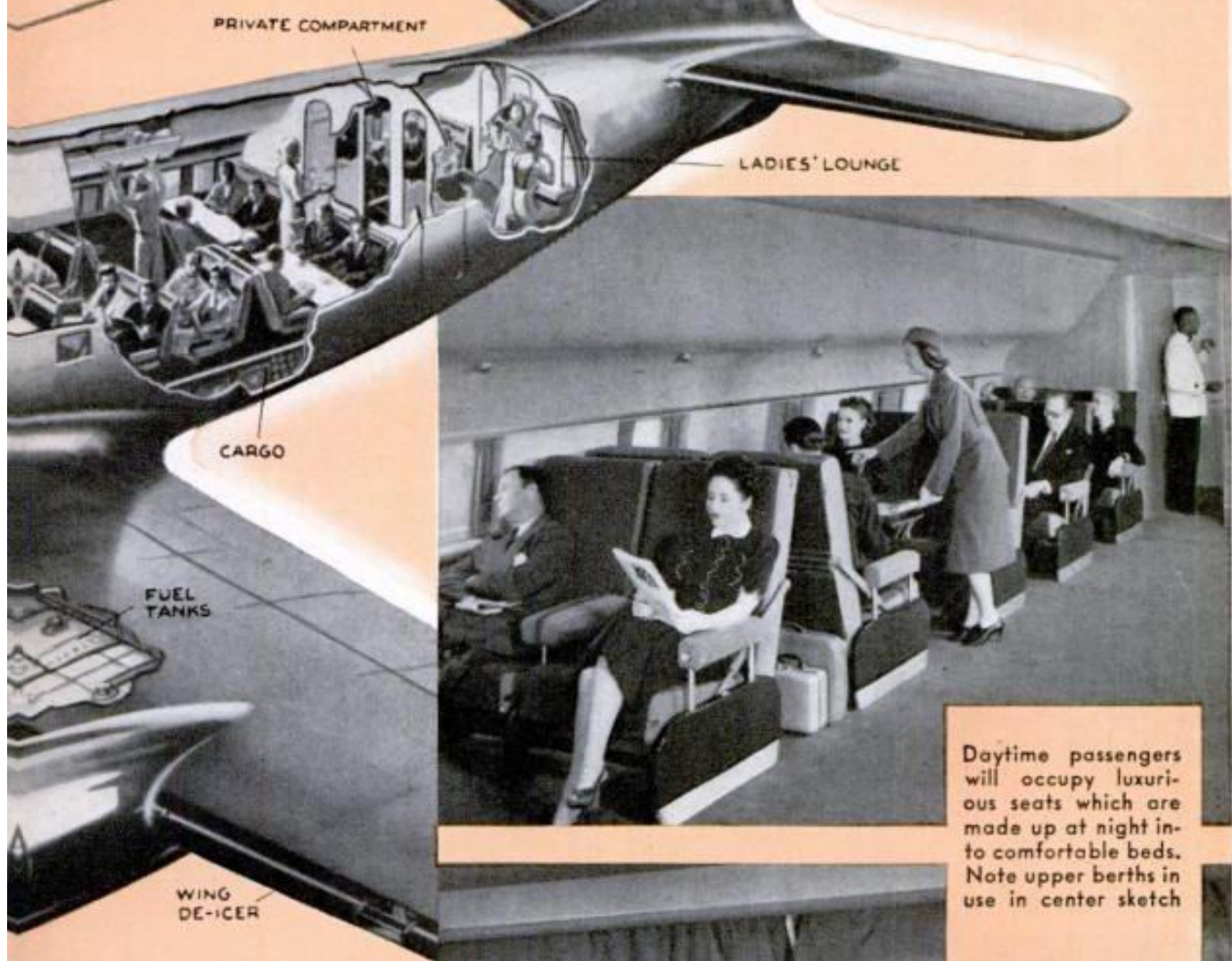
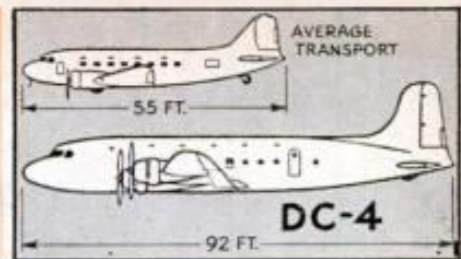
been experimenting on the ground and in the air, offering themselves as human guinea pigs to test the apparatus which makes sub-stratosphere flying possible. Within two tanks, hidden from prying eyes at the Douglas Aircraft Company plant in Santa Monica, Calif., actual conditions of high-altitude flight were recreated inside and outside of a plane cabin. Here pressures were studied, with all instruments operating as in flight. Nearby, an entire section of cabin was erected, and pressure within was built up to test walls and bulk-heads for stresses and expansion.

At Seattle, Wash., Boeing engineers carried a Stratoliner to the "upper level" sixty times, yet it



The new Douglas DC-4 in which American travelers soon will be flying. Left, its cockpit

never left the factory floor. Sixty times, compressed air was pumped into the sealed cabin, inside which rows of 100-pound lead bars represented the thirty-three passengers to be carried, while heavy weights were suspended from the tail to exceed flight loads set up in bumpy air and in unusual maneuvers. To their amazement, they found that the internal air pressure of the cabin actually strengthened it. To make sure the cabin was really air-tight, workmen smeared a film of soap



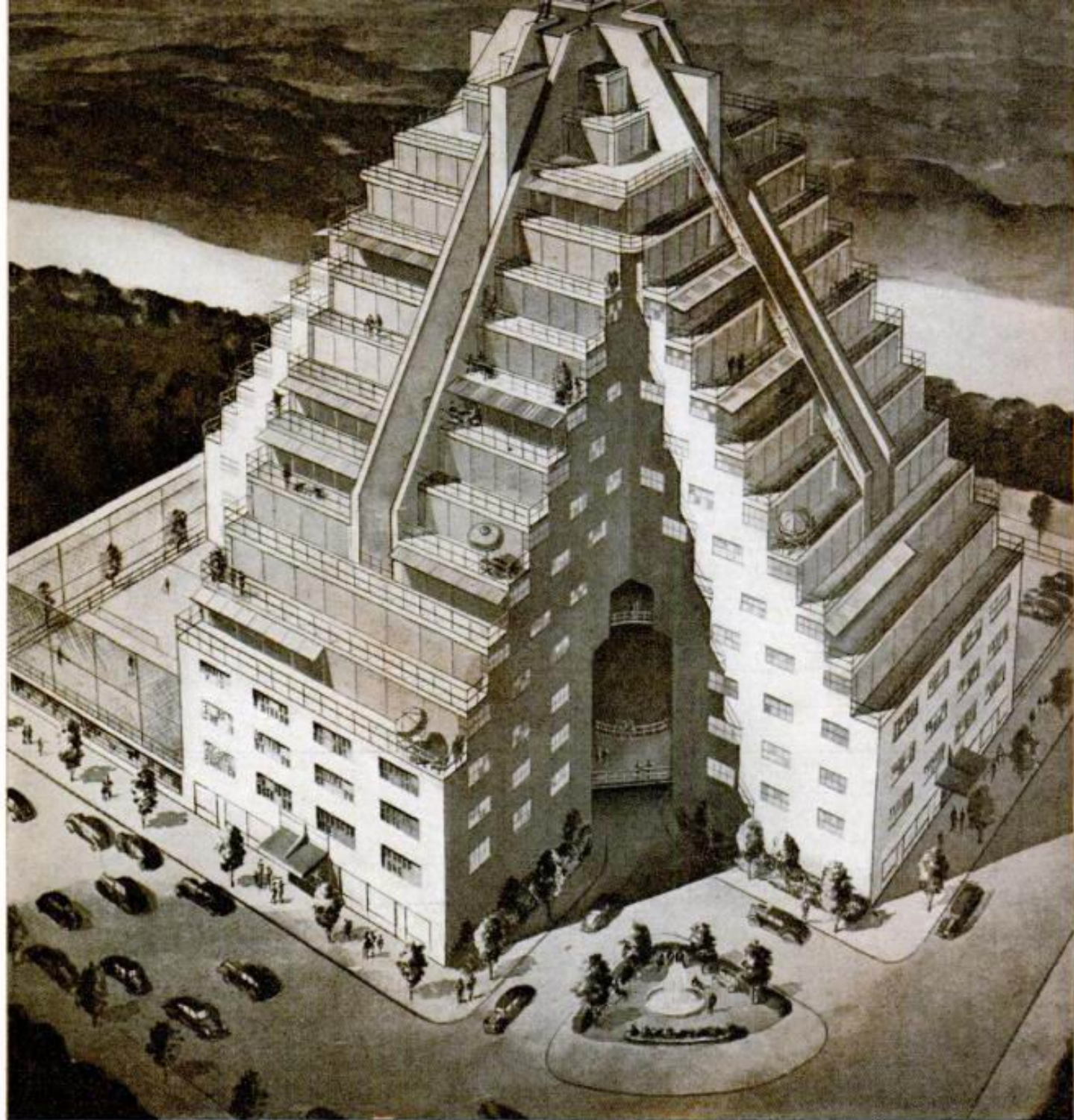
Daytime passengers will occupy luxurious seats which are made up at night into comfortable beds. Note upper berths in use in center sketch



over the metal seams and rivets; then watched for telltale bubbles.

In flight, a pair of superchargers or "blowers," driven by two of the engines, force air taken in at the leading edge of the wing into the cabin. Heaters maintain the air temperature at seventy degrees.

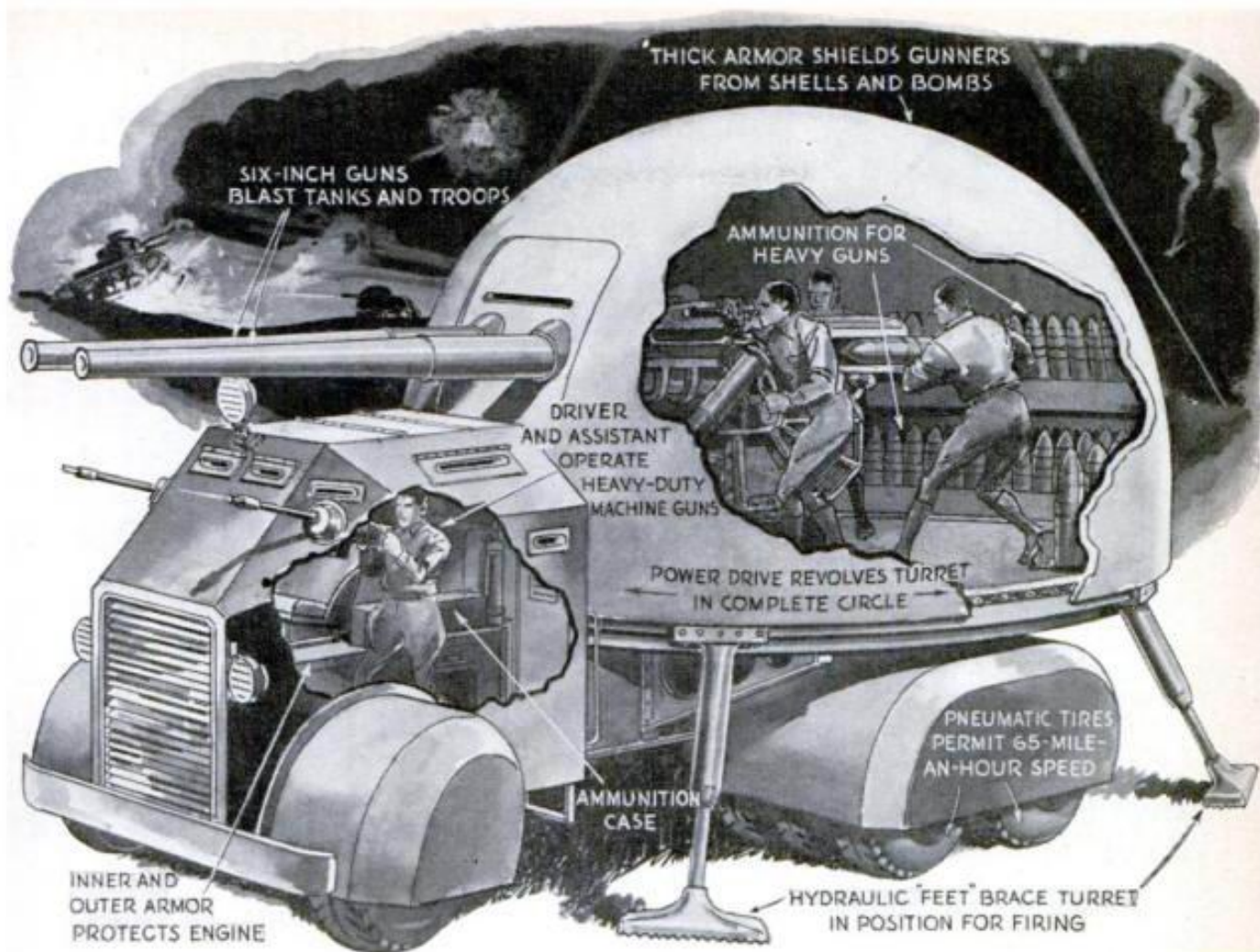
If you take an imag-



Pyramid Apartment House

EVERY tenant has an outside apartment in a pyramid-shaped house designed by Edwin A. Koch, New York architect. Some time ago, Koch planned a bank of apartments for a steeply sloping hillside. Then the bold idea occurred to him of joining four of the dwellings, back to back in a pattern like a cross, with the result shown above. Carrying modern set-back architecture to its logical extreme, the huge building provides a private terrace, with penthouse airiness, for every tenant above the fourth floor. No windows face the interior, a nat-

urally ventilated hollow core fourteen stories high. Its base of sixty-four-foot diameter provides ample space for cars to discharge and pick up passengers at passageways leading to the elevators. Pedestrians use exterior doors. Apartments are supplied from a central plant with washed, humidified, and heated air in winter and with unheated air for summer coolness. Open corners of the building's cross-shaped base provide a two-way automobile drive, a parking space for visitors, and two covered garages for tenants.



Mobile Pill-Box Fortress Mounts Two Six-Inch Guns

PILL BOXES on wheels, armed with twin six-inch guns in revolving turrets, may prove a formidable new weapon for U. S. defense. Racing to an unprotected area threatened with invasion, they would transform it overnight into a fortified zone whose strong points could be shifted at will to

meet the changing battle picture. The drawing above shows unofficially reported details of an experimental model built by a Los Angeles, Calif., truck manufacturer. Subjected to four months of tests by Army engineers, it is said to have attained a speed of sixty-five miles an hour.



How a gunner may aim his rifle around corners or over the top of a parapet with the new sight



Sharpshooters Fire from Cover with Periscope Rifle Sight

SHARPSHOOTING acrobatics are made possible by a new L-shape "periscope sight," designed to fit any standard military rifle. Without exposing himself to enemy fire, an infantryman using the sight may look, aim his gun, and then fire it around a corner of a building, or over the top of a protecting parapet, without exposing himself to the fire of enemy sharpshooters. The sight is being demonstrated at the left.

In the same year, the young astronomer was married. His wedding trip carried him to the Lick Observatory, in California. Soon afterward, he visited Europe and found the fame of his spectroheliograph had preceded him. At twenty-three, he was already considered an authority on the sun. After a year abroad, spent principally studying in Berlin under Helmholtz, Planck, and other famous physicists, he returned to Chicago.

Although he was then only twenty-four, his friend, President Harper of the newly founded University of Chicago, made him associate professor of astrophysics. It was not long before George Hale and Harper were deep in plans for an observatory big enough and complete enough to carry the astronomer's researches to their logical conclusion. The little twelve-inch telescope in his Kenwood observatory was satisfactory only for preliminary studies. He had been deeply impressed with the thirty-six-inch instrument at Lick. It was then the world's largest and Hale had come home with an ambition to own one like it. Once provided with a *large* telescope, he could indeed lead the world to something new.

ABOUT this time, Hale attended a scientific meeting in Rochester, N. Y. Purely by chance, he overheard somebody talking to the great lens maker, Alvan G. Clark. Clark was in a quandary. The University of Southern California was sponsoring a scheme for outdoing Lick and building a telescope even larger than the thirty-six-inch instrument. After two huge forty-inch disks were in Clark's workshop ready for grinding, word came from California that an expected gift of money to pay for the lens was not forthcoming. The University couldn't even pay for the glass. Clark was out of pocket \$20,000 and, as there was no one else in America who could possibly afford such a telescope, the great disks were

likely to be left on his hands, orphans.

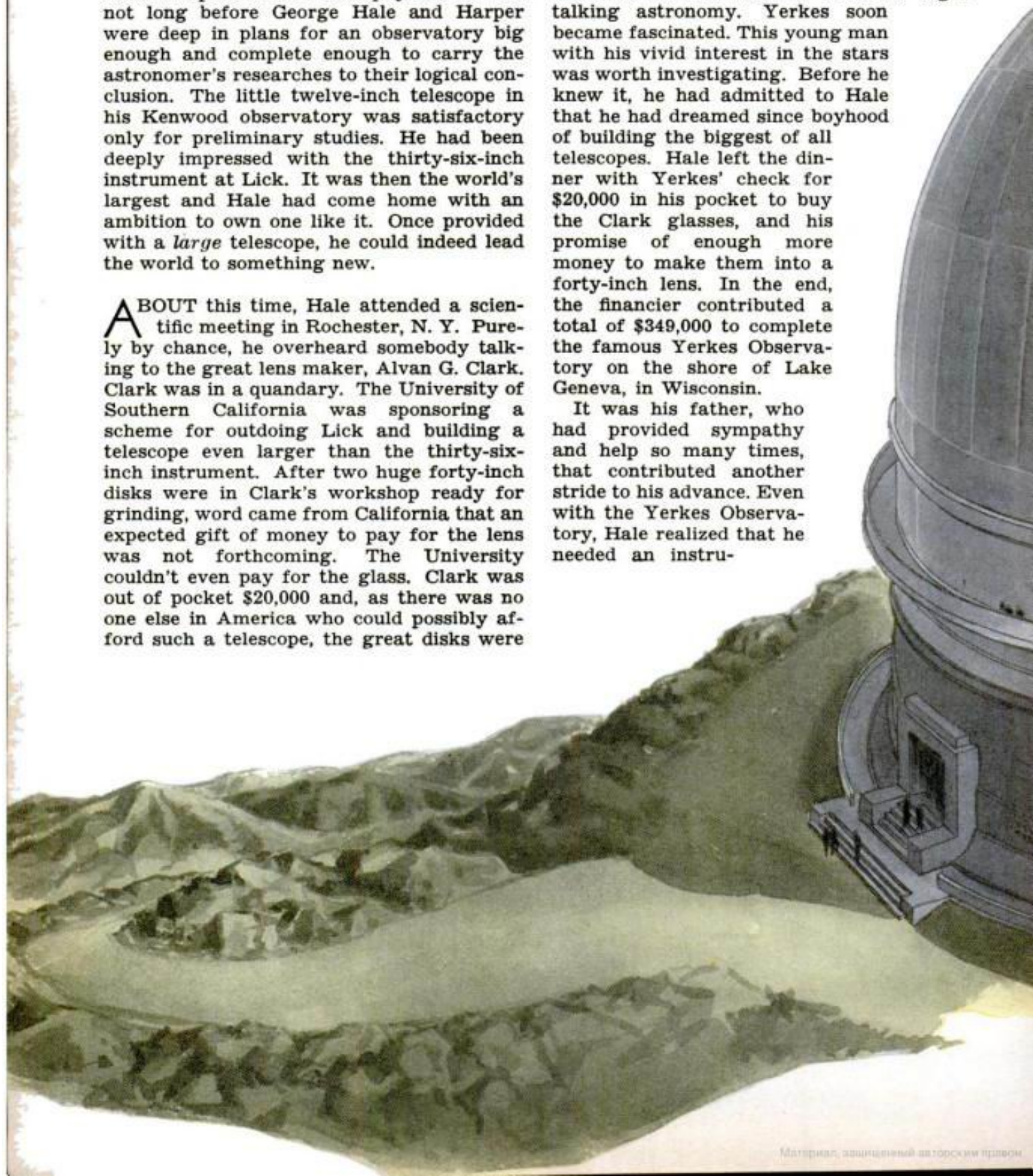
Hale rushed back to Harper with the news. Ready to their very hands, he said, were glass disks large enough to make the most powerful telescope in the world. But where was the money to come from?

"What are you going to do?" Harper asked.

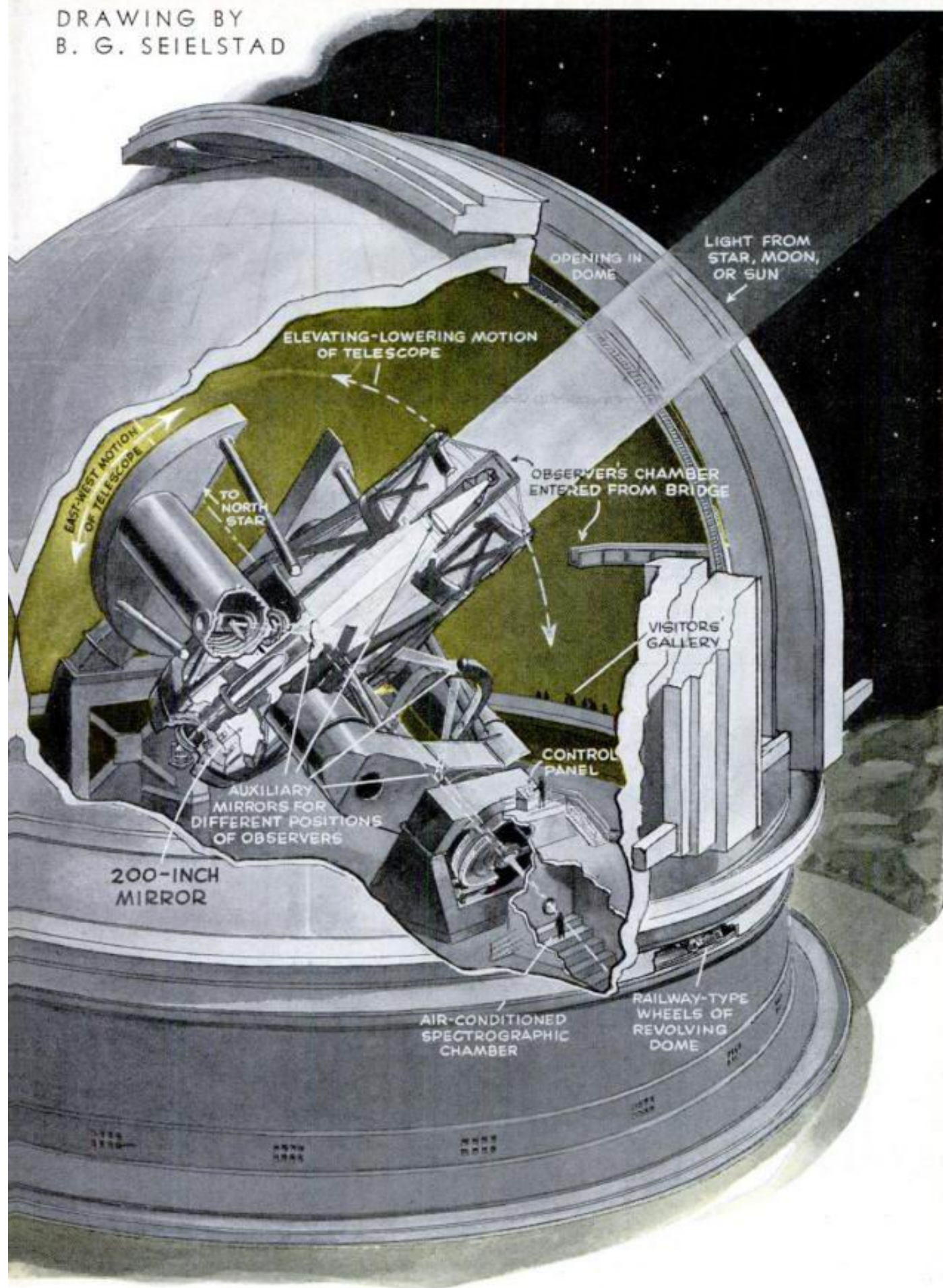
"See Charles T. Yerkes," said Hale.

Yerkes was one of Chicago's most wealthy men—and most influential. Hale laid his plans carefully. He got himself invited to a dinner that Yerkes was to attend and contrived to sit next to him. Then he began talking astronomy. Yerkes soon became fascinated. This young man with his vivid interest in the stars was worth investigating. Before he knew it, he had admitted to Hale that he had dreamed since boyhood of building the biggest of all telescopes. Hale left the dinner with Yerkes' check for \$20,000 in his pocket to buy the Clark glasses, and his promise of enough more money to make them into a forty-inch lens. In the end, the financier contributed a total of \$349,000 to complete the famous Yerkes Observatory on the shore of Lake Geneva, in Wisconsin.

It was his father, who had provided sympathy and help so many times, that contributed another stride to his advance. Even with the Yerkes Observatory, Hale realized that he needed an instru-



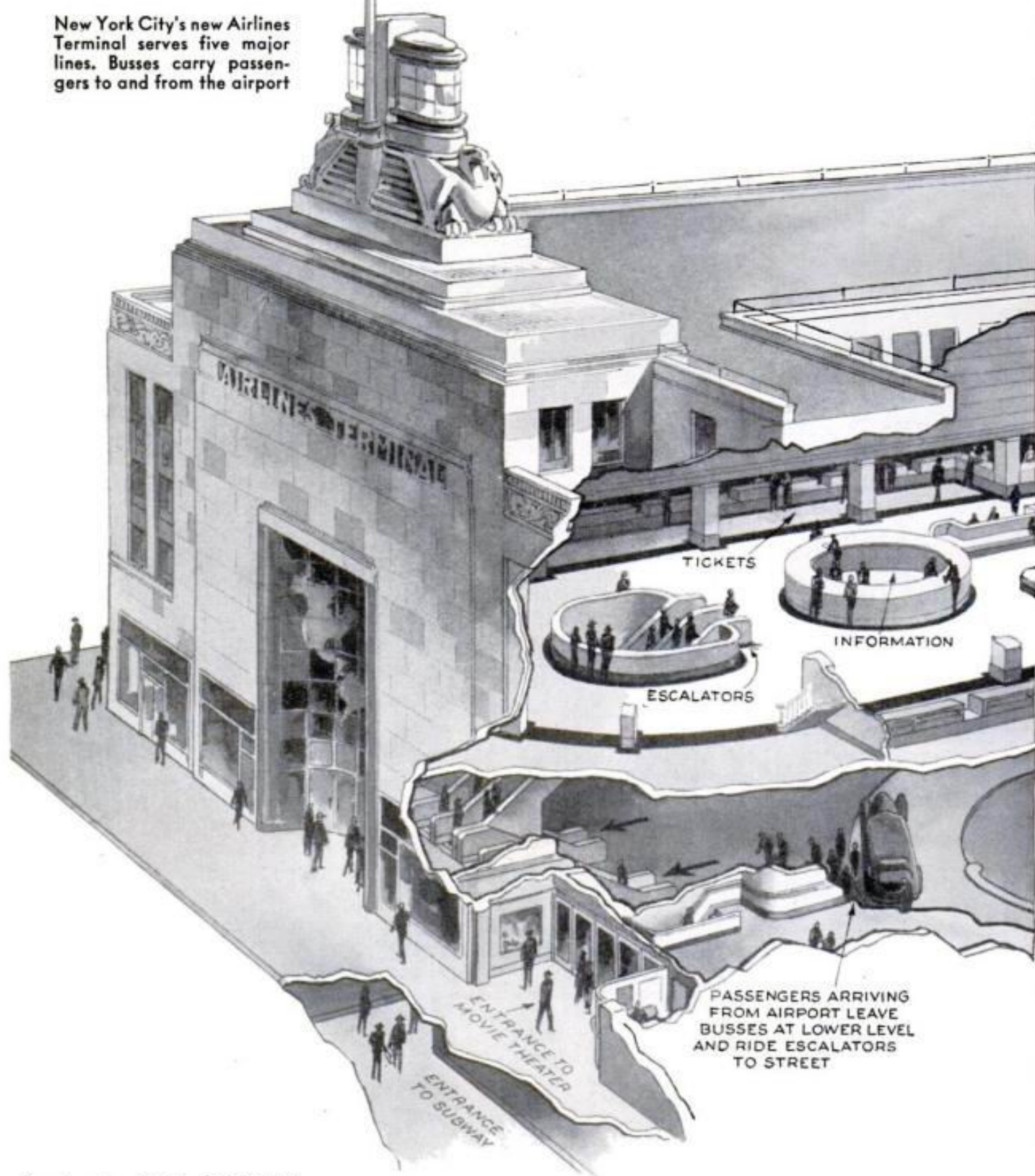
DRAWING BY
B. G. SEIELSTAD



THE GLASS GIANT OF PALOMAR. How the 200-inch eye will be mounted under its huge shell, taller than a fifteen-story building, atop a mountain a mile above the sea

Grand Central Station of the Skyways

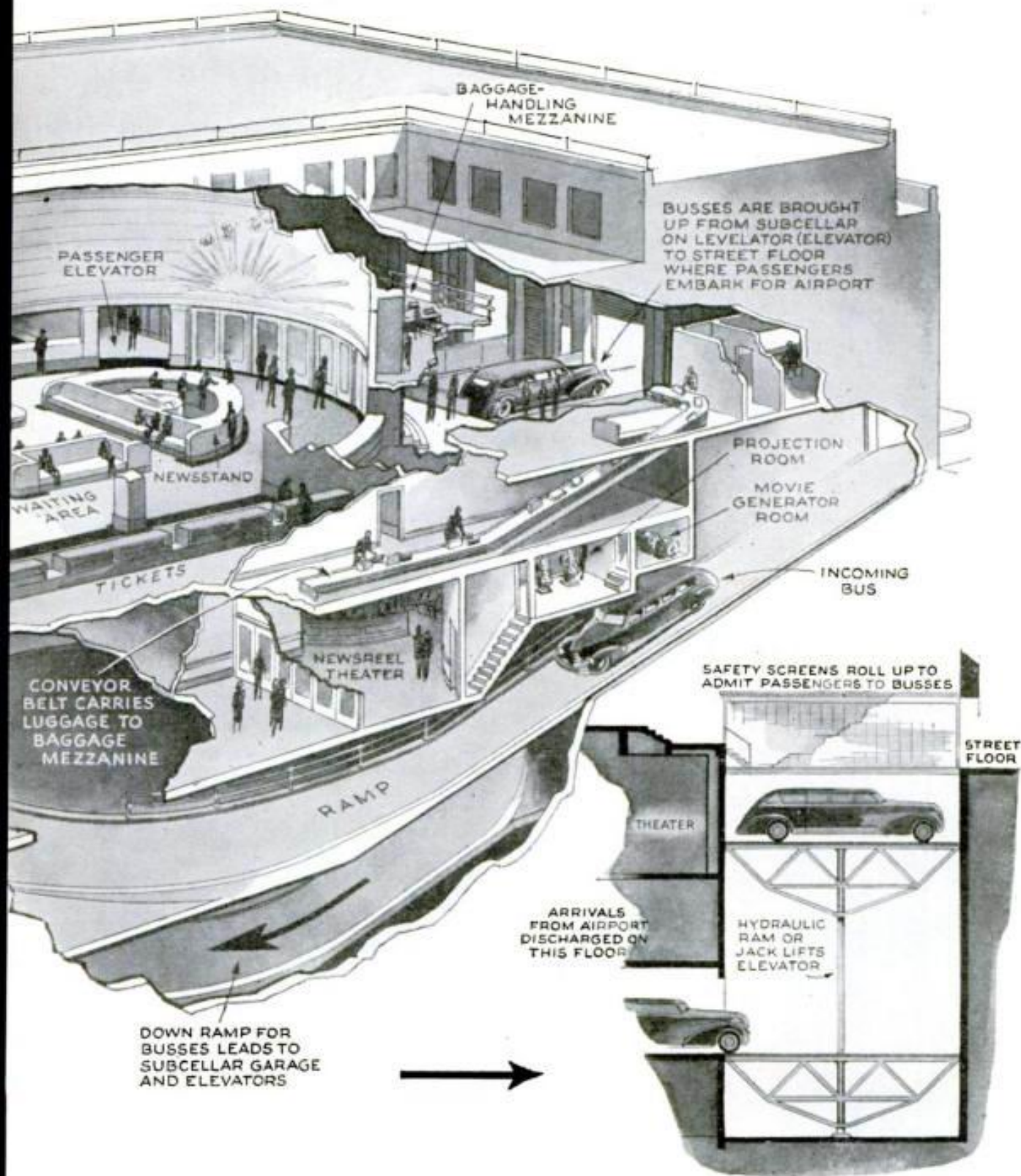
New York City's new Airlines Terminal serves five major lines. Busses carry passengers to and from the airport



Drawing by B. G. SEIELSTAD

TRAVELERS flying to and from New York may now pass through the first building of its kind in the world, the city's recently opened Airlines Terminal on 42nd Street opposite Grand Central Station. Although it is eight miles from the municipal airport, LaGuardia Field, the terminal was built and is operated by the five major airlines serving the city—United, T.W.A., American, Eastern, and Pan-American. Designed by

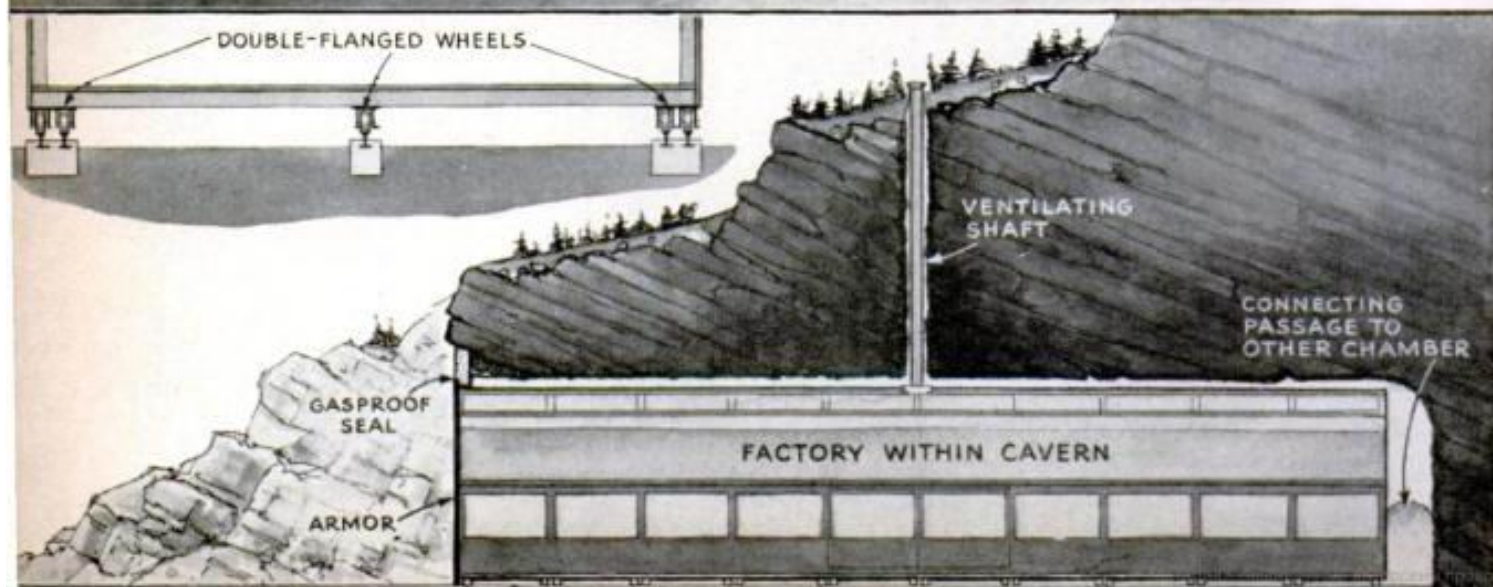
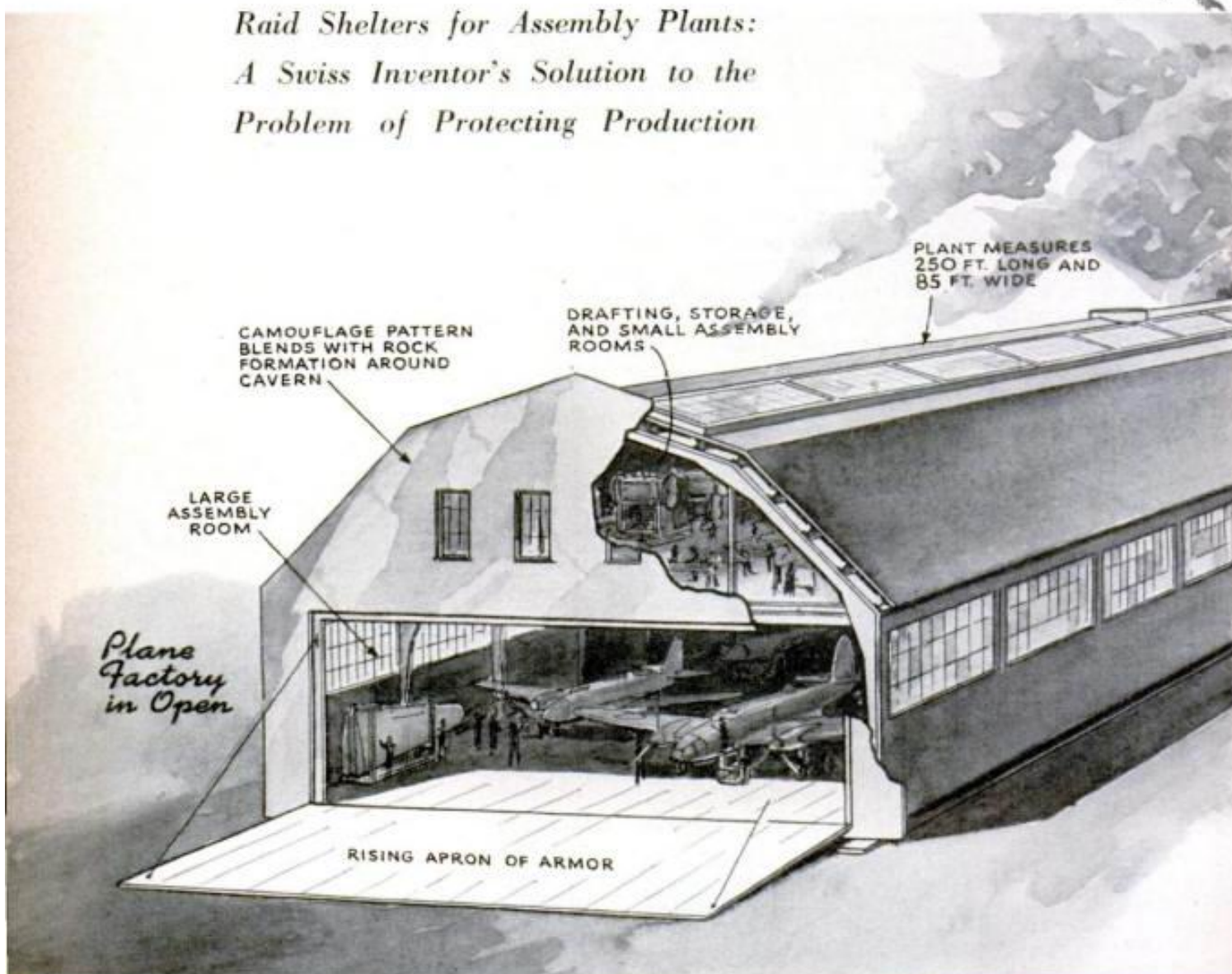
John B. Peterkin, the terminal was planned so that there would be no conflict between streams of arriving and departing passengers, who are handled on different levels of the building. They are carried to and from the airport in limousine busses, and the terminal has a capacity of 72 of these every hour. An independently operated motion-picture theater, showing short programs of newsreels, also has space in the building.



Bombproof Plane Factories

ROLL INTO MOUNTAIN SIDE

*Raid Shelters for Assembly Plants:
A Swiss Inventor's Solution to the
Problem of Protecting Production*





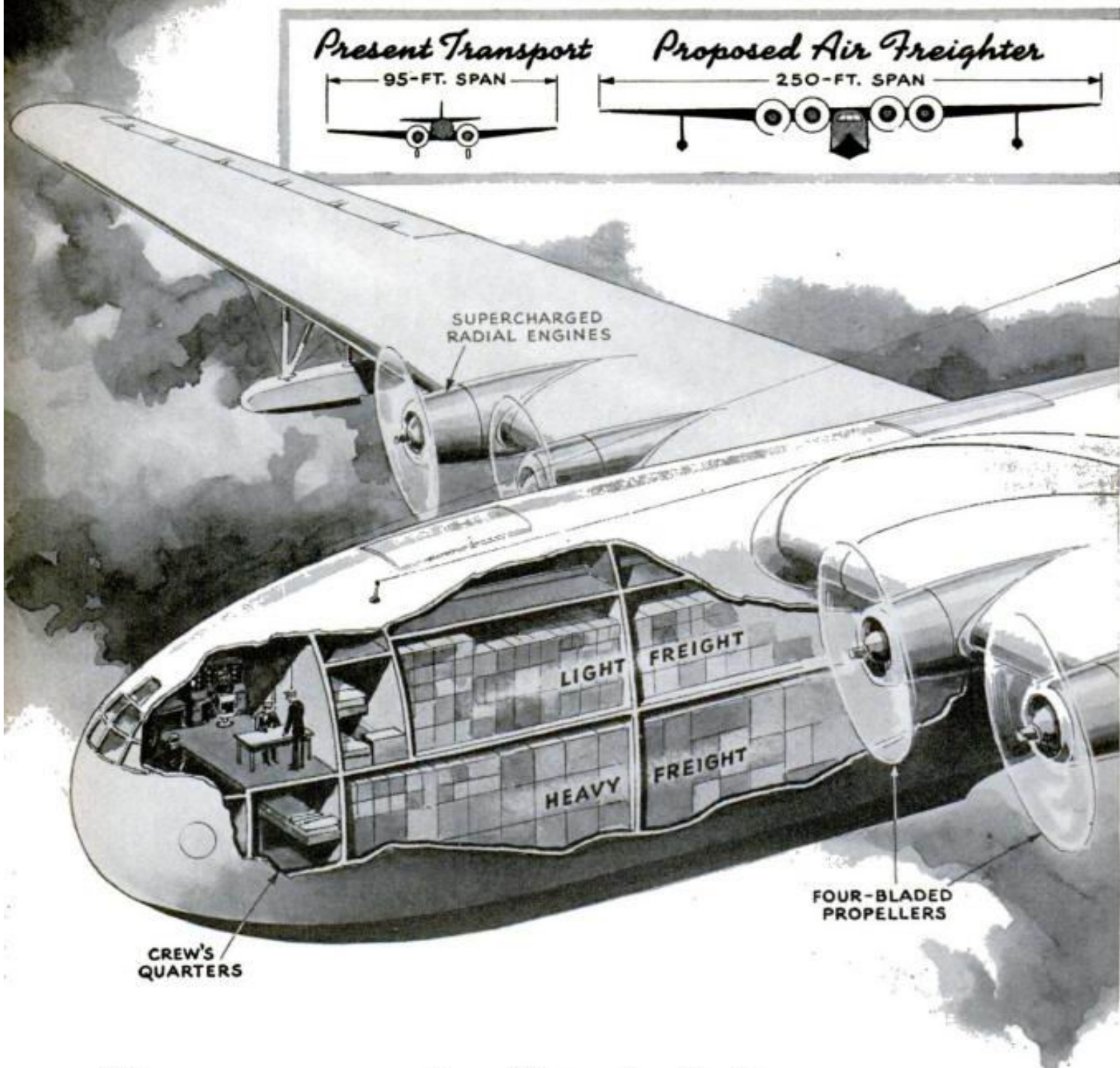
DRAWING BY
B. G. SEIELSTAD

Disappearing airplane assembly plants. One is shown operating in the open, the other hidden in the hill as for an air raid

AIRPLANE FACTORIES that literally run to shelter from raiding bombers have been invented by Antoine Gazda, noted Swiss armament designer, and erected at undisclosed places in Switzerland by the Pilatus aircraft concern as a national-defense precaution. A typical installation consists of a pair of twin assembly plants, normally standing in the open where their total of 360 workers enjoy natural sunshine and fresh air. At an air-raid alarm signal, however, a "motorman" enters a control cabin at the rear center of each plant's upper floor. He swings a switch handle, and the entire 1,600-ton factory rolls ponderously on electric-powered wheels into

a cavern in a mountain side, completing its strange journey in about twenty minutes. Only its front remains exposed, and steel armor covers this end.

Meanwhile, workers reconnect quick-change electric and plumbing fittings to mains within the cavern, and attach a ventilating tube whose intake is hidden. Then the plant resumes full operation under artificial-daylight lamps. In case of a poison-gas attack, the front portal can be hermetically sealed, and fresh air drawn in through the ventilator is filtered and purified. When danger has passed, an "all clear" signal from observers brings the factory out into the open again.

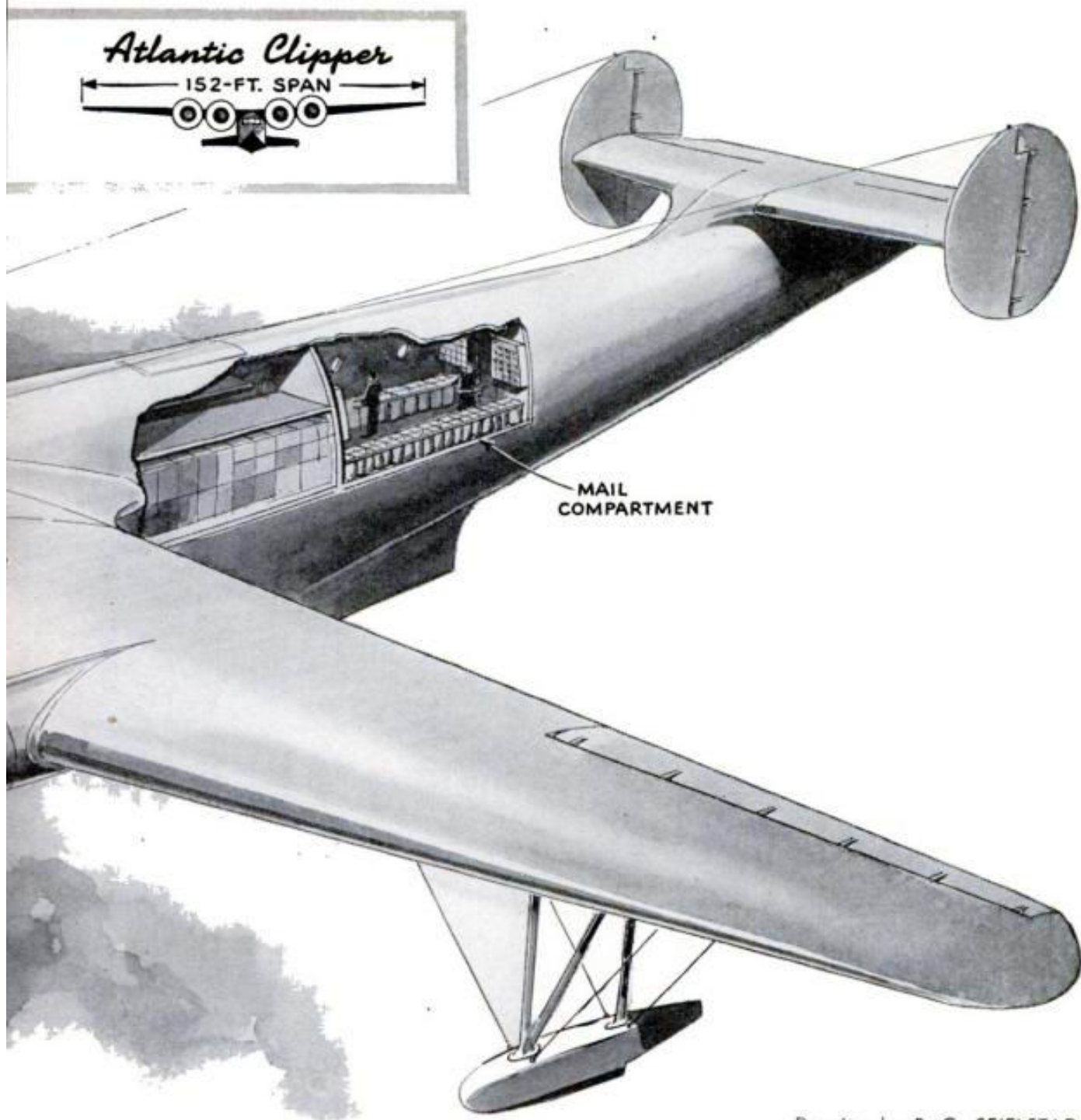


Tomorrow's Freighters

FREIGHTERS with wings, hauling 80-ton cargoes 3,500 miles without a stop, are more than an aviator's dream. According to Glenn L. Martin, Baltimore airplane manufacturer, they are a logical development of the aviation industry. The construction of planes capable of such performance, weighing 380,000 pounds, could be started tomorrow if somebody should order one.

Paradoxically, the destruction of the present war will speed the development of air freighters, their size to be determined by the business available, Martin believes. This is because the war is teaching airplane manu-

facturers to turn out bigger, better, and speedier planes by mass-production methods. It is pushing aeronautical research far beyond the point to which it would have progressed under more normal conditions in an equal period of time, and at the same time is destroying sea-borne cargo carriers at such a rate that a serious shortage already exists. Thus, when the war ends, exporters can be expected to turn to the air for a means of transportation that can be produced rapidly to replace the lost ships, and will also get the freight to its destination faster than would be possible by any



Drawing by B. G. SEIELSTAD

method of transportation on land or water.

Martin, who flew an early "air express" in 1912 when he carried newspapers and mail in a plane, and whose factory has turned out some of the world's biggest planes, is not telling what the detailed specifications of a 190-ton air freighter would be. But he already has the drawings for a 65-ton luxury passenger airliner, a step in the right direction, and his factory is building a plane, presumably a bomber, which will be the U. S. Navy's largest flying boat.

He has no fear that postwar conditions will cause a slump in the aviation industry.

Before the war began, he points out, it was the nation's fastest-growing industry. War-stimulated growth will enable it to pick up commercial plane production when the war ends years ahead, in progress, of where it would otherwise have been.

The not-far-distant future will see a system of harbors, landing fields, docks, and warehouses serving air freighters as railroads and ships are now served, Martin believes. He sees in air freight a new frontier for Americans, with thousands of new jobs for workers and vast new fields of investment for capital.

A

Model Studio Is Built For Television

WHEN the new television broadcasting studio of the General Electric Company station W2XB goes into service, in late spring or early summer, it will represent the last word in image transmission. A large remodeled clubhouse at Schenectady, N. Y., houses facilities unavailable in outgrown quarters. Transmitting equipment employs a battery of six television cameras. Three of them pick up scenes in the main studio, a soundproofed room measuring 70 by 46 by 18 feet and occupying most of the main floor.

The cameras may be focused on a single scene, from different angles and distances, or may be used on different sets of the big

SIX SMALL TELEVISION RECEIVERS
SHOW PROGRAMS BEING BROADCAST
OR READY TO GO ON AIR.
(CHOICE OF THREE PROGRAMS OR
POINTS OF VIEW IN MAIN STUDIO AND
THREE MOVIE FILMS IN AUXILIARY STUDIO)

Control Room

ENGINEERS MONITOR
IMAGES AND SOUND

THREE TELEVISION
CAMERAS BROADCAST
MOVIE FILMS

Auxiliary Studio

OBSERVATION
WINDOW

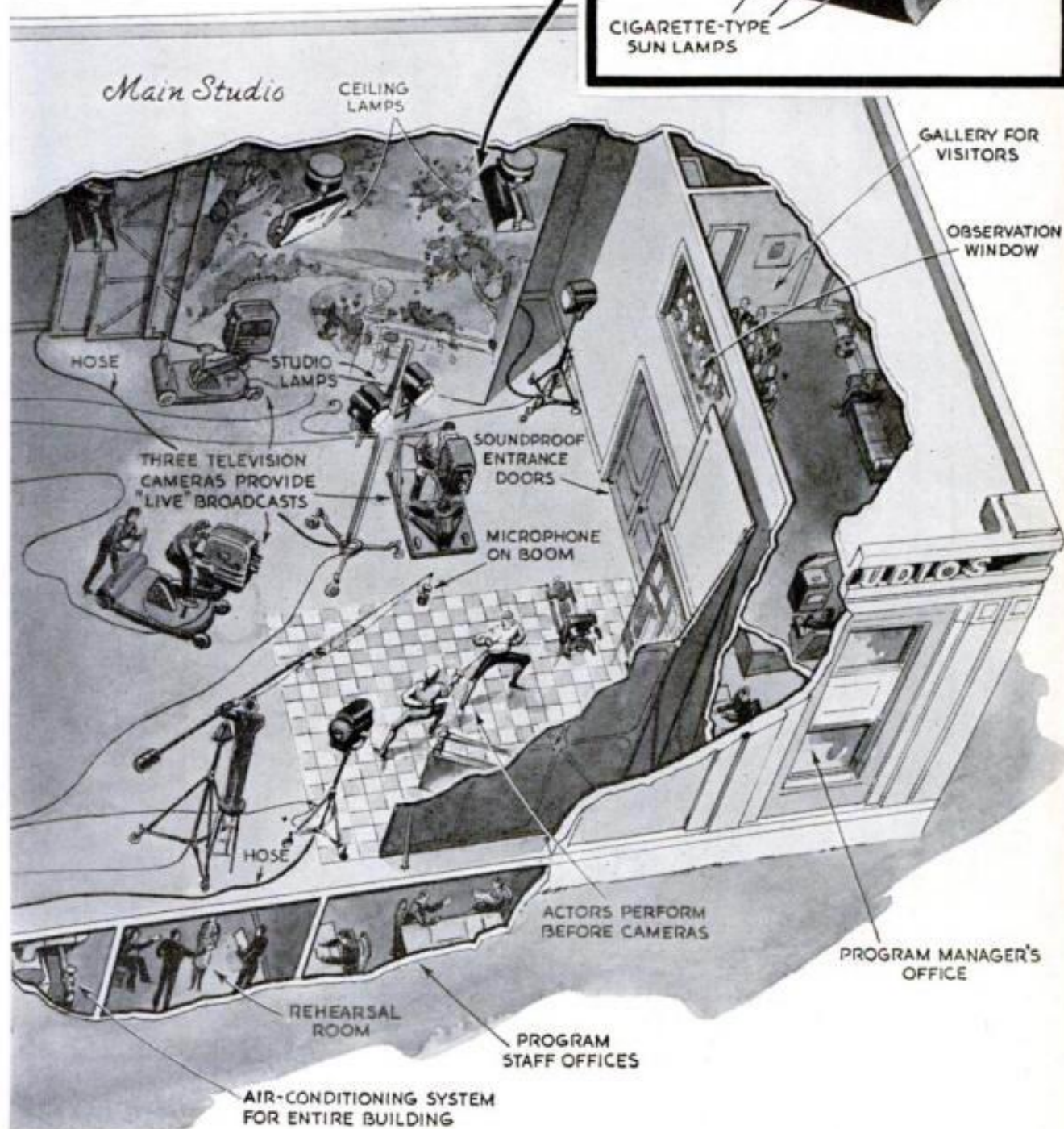
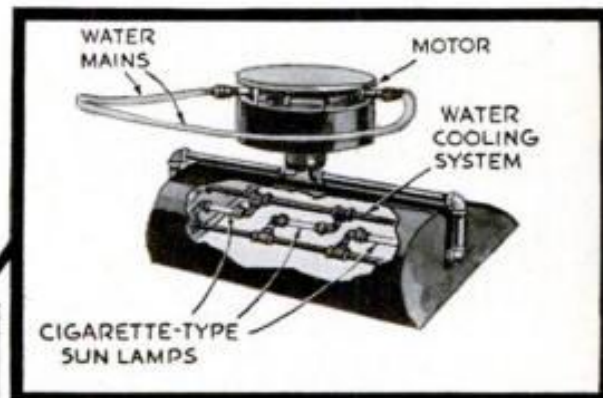
TRAP DOOR TO
SCENERY AND
PROPERTY ROOM
IN BASEMENT

OPERATOR
CONTROLS
LIGHTING

stage. An auxiliary studio contains three more cameras for telecasts from movie film. In a control room, radio engineers monitor sight and sound. They switch from one camera to another, aided by six screens showing what is on the air and what is ready. Through a large observation window, they command a direct view of the main studio, while a similar window at the opposite end serves a like purpose for visitors.

Intense illumination required for television is provided by ceiling fixtures containing midget mercury lamps of General Electric's recently developed "cigarette" type, and by powerful studio lamps on the floor,

both water-cooled. The entire building is air-conditioned for comfort. A 125-foot-tall antenna will relay the programs to the main transmitter in the Helderberg Mountains, 12 miles outside of Schenectady. In winter, this antenna will be heated electrically to prevent ice formation.



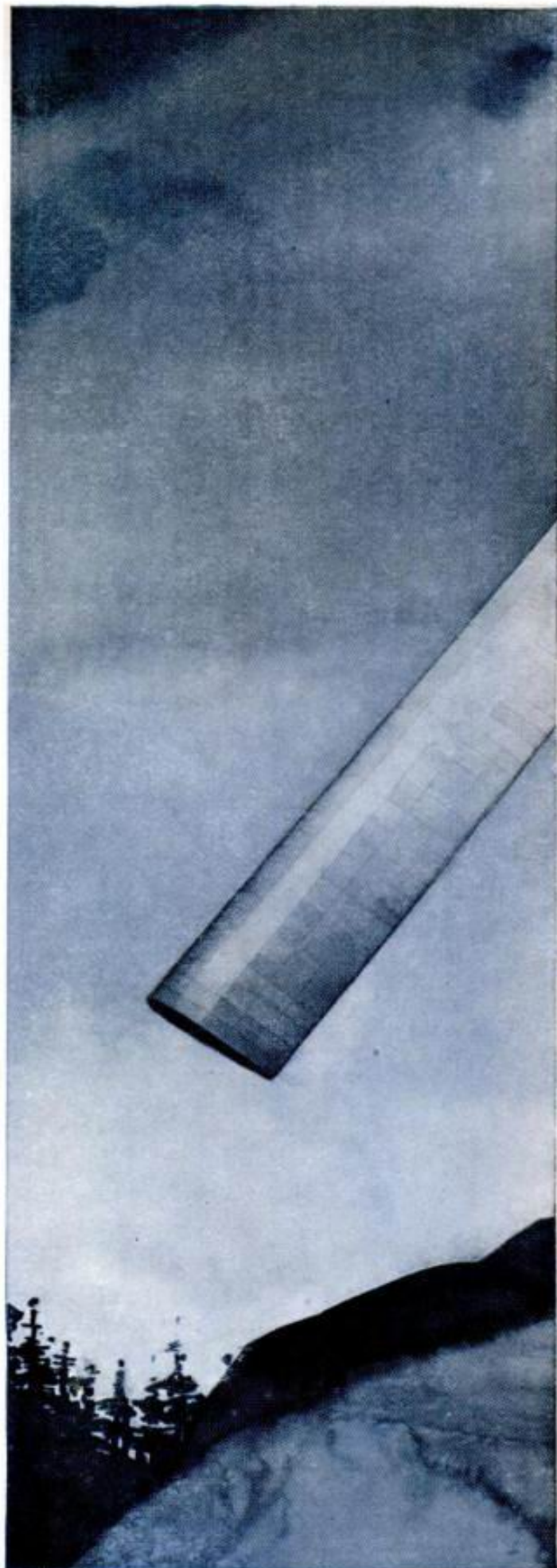
vised the basic pattern of the wind turbine. Later, more than seventy variations were worked out on paper. The Library of Congress, as an aid to the research, prepared a bibliography on wind turbines that included 1,400 titles. Finally, six different models were put through performance tests in ten consecutive 24-hour days at the Leland Stanford wind tunnel, in California. At times, as many as three different engineers were tackling the same problem and, all told, more than 200 trained scientists, under the general direction of Dr. J. B. Wilbur, head of the Structural Analysis Laboratory at M.I.T., aided in the refinement of detail.

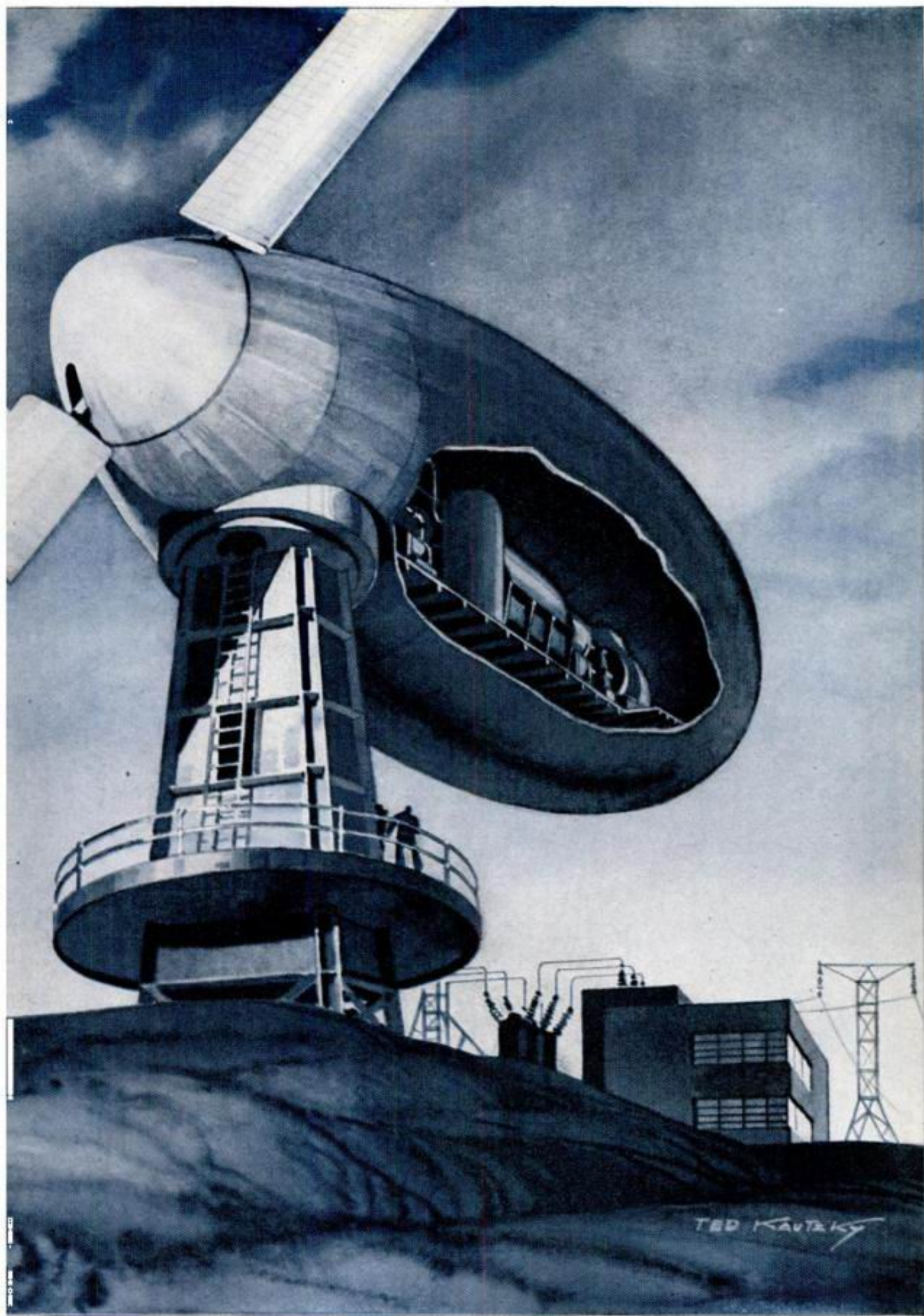
The hardest nut to crack was to keep the great windmill spinning in gusty weather at the uniform pace demanded for the production of alternating-current electricity. Two features of the design have solved the problem: the use of variable-pitch blades and the fact that the station's output will flow through the same circuit as current from a neighboring hydroelectric plant. If a sudden gust tends to speed up the windmill before the blades can be adjusted to the new wind velocity, the mountain-top station will automatically take on part of the load of the hydro plant. The effect is the same as though the two generators were connected with a long, flexible shaft. If one generator, under such conditions, started to speed up, it would have to twist the shaft as well as carry its normal load. This "electrical brake" is counted on to prevent sudden, violent fluctuations in speed.

While the first installation is being made on a mountain top, meteorological surveys indicate that suitable winds exist at such diverse locations as the great plains and on certain marine islands.

Success in this attempt to harness the wind of a New England mountain top to the production of electricity will have special importance at this time. Wind turbines would provide a new, cheap source of power for rapidly expanding defense industries. They could function where water power is unavailable, and they could be erected in one-third the time required to build hydroelectric stations of the same capacity. And such generators, scattered among the hills, would be far less vulnerable to attack from the air in wartime than larger and more obvious hydroelectric plants, or steam-powered generating plants which are usually located in congested industrial areas.

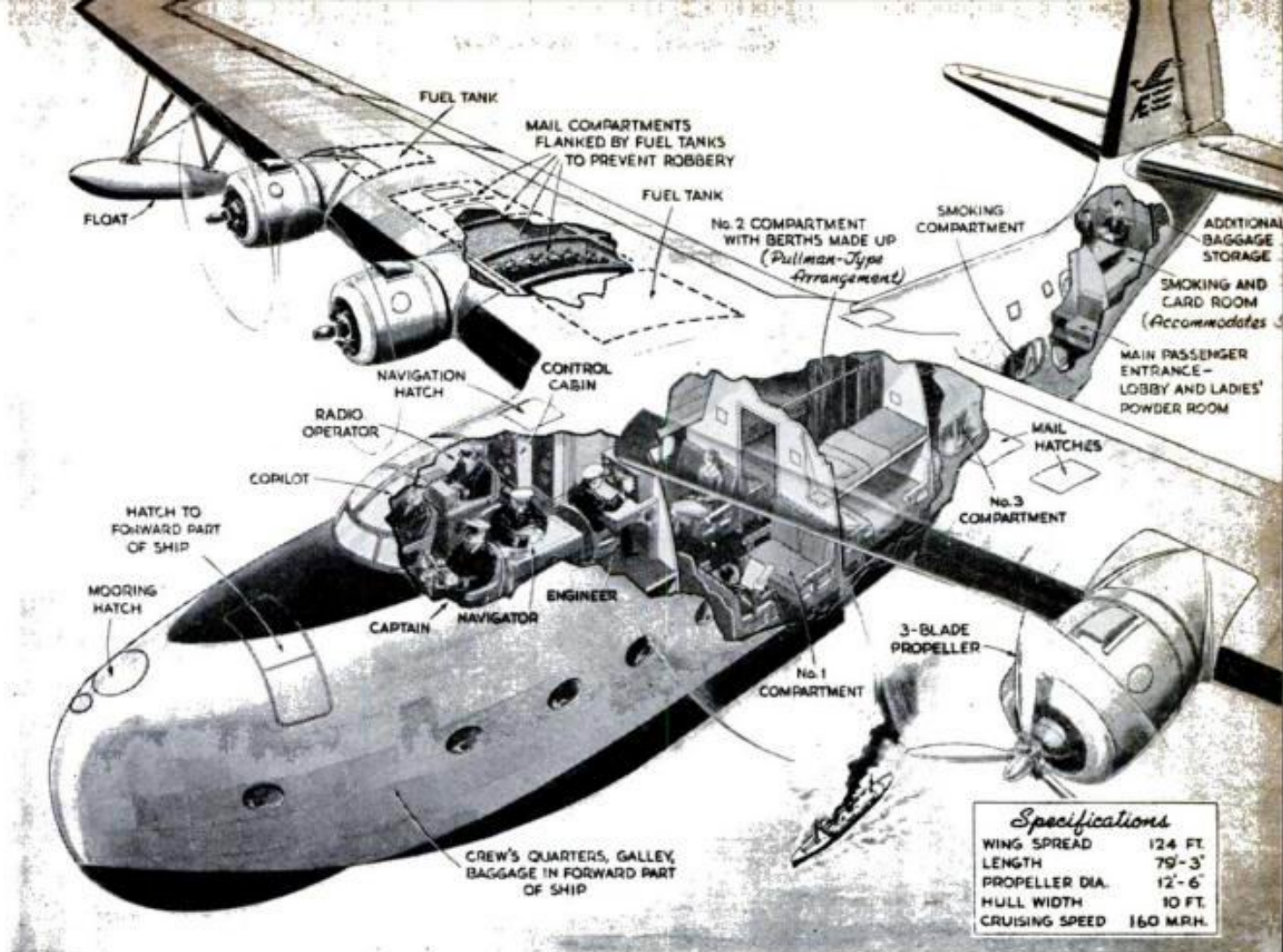
An artist's idea of what the huge windmill will look like when it is completed this month. The housing for the generating equipment is 50 feet long and 20 feet around, and tilts down to face the mountain updrafts. Each blade is as big as the wing of an army bomber





JULY, 1941

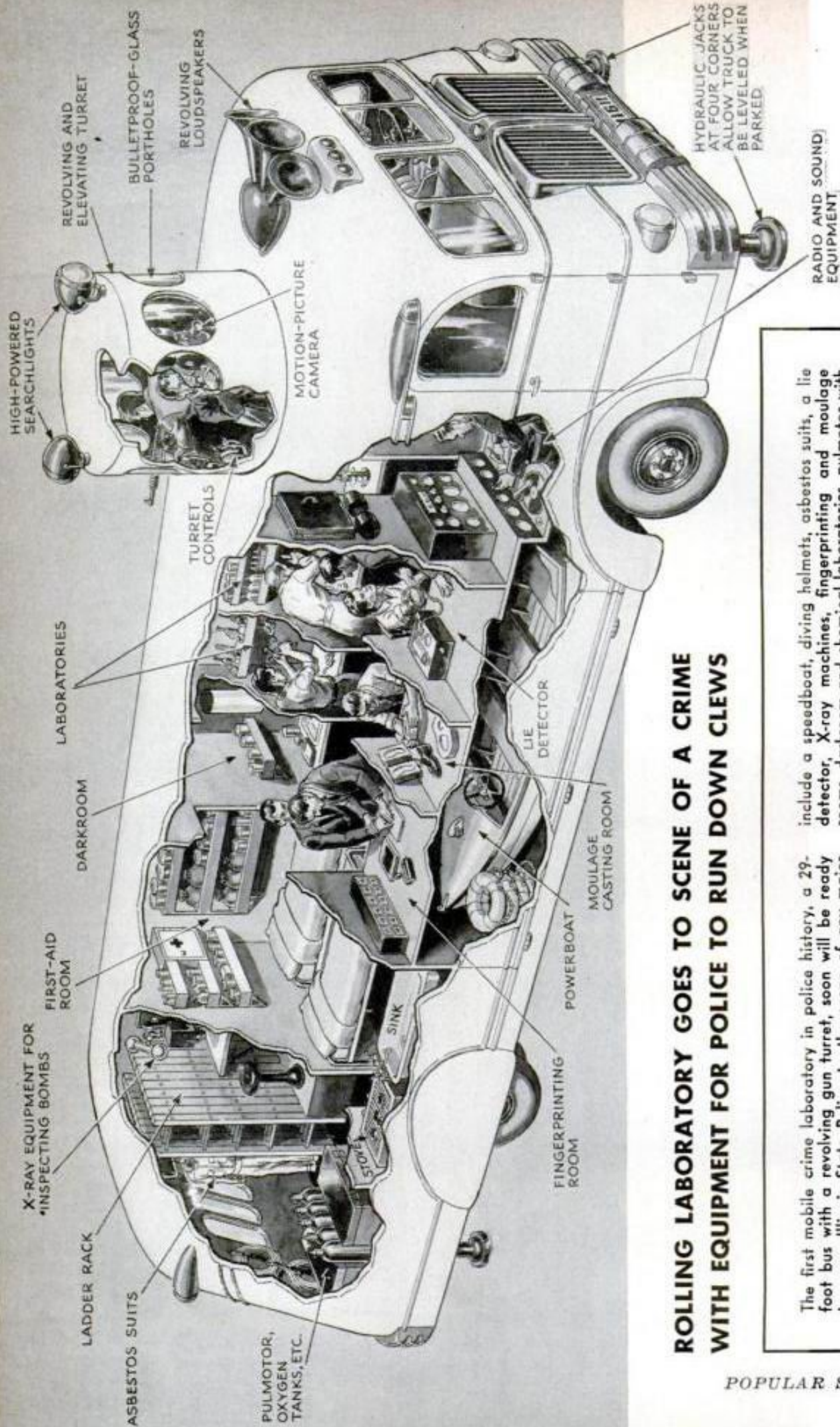
117



LINER OF THE SKY. A commercial counterpart of the Navy's "Flying Dreadnought," the VS-44 sleeps 16 passengers, has daytime space for 40. It has a top speed of 225 miles an hour. Fuel tanks hold 3,900 gallons of gasoline—enough to take the plane 4,700 miles at its cruising speed of 160 miles an hour

TO SHIPS SERVING AS FLOATING METEOROLOGICAL STATIONS



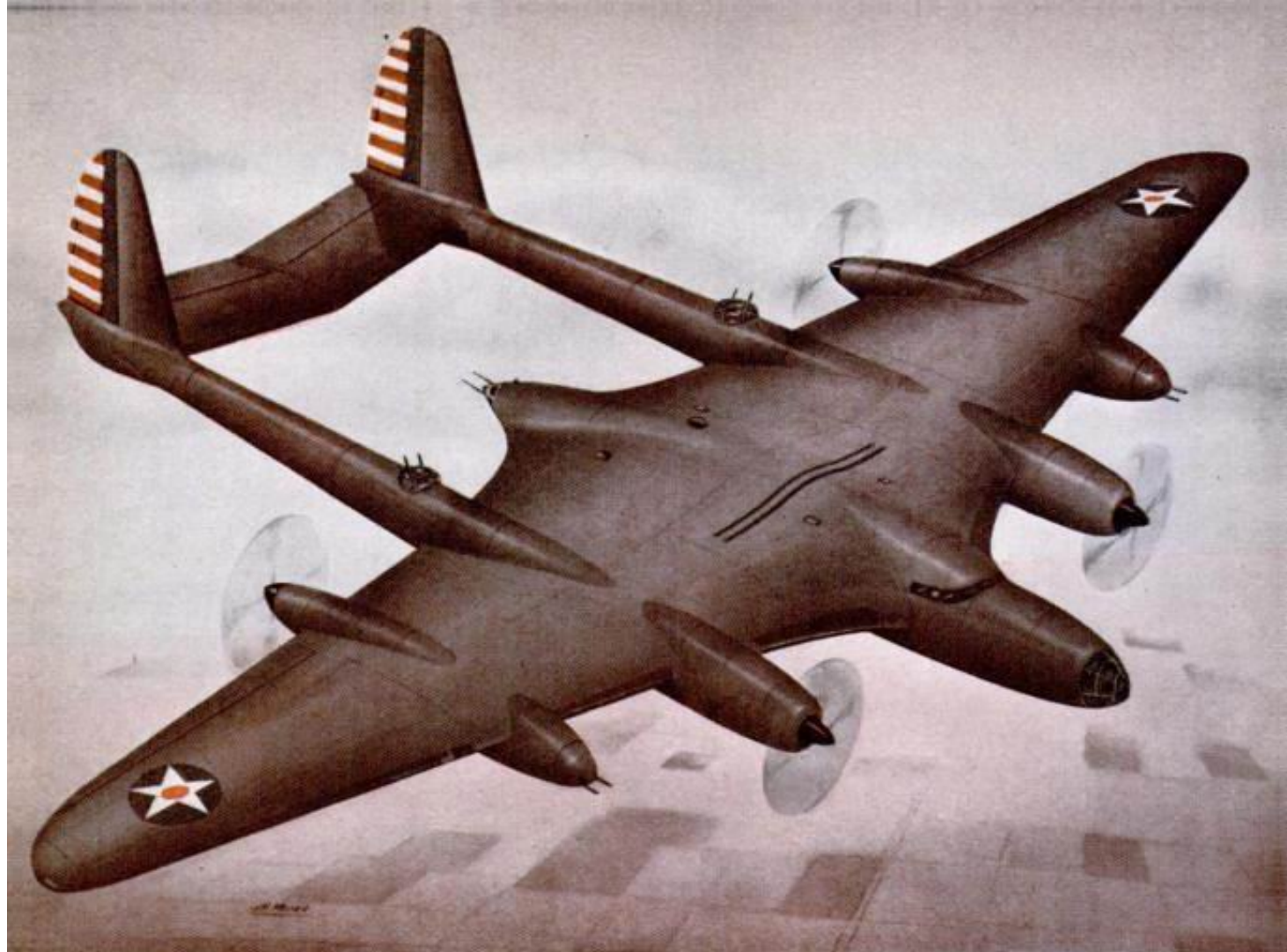


ROLLING LABORATORY GOES TO SCENE OF A CRIME WITH EQUIPMENT FOR POLICE TO RUN DOWN CLEWS

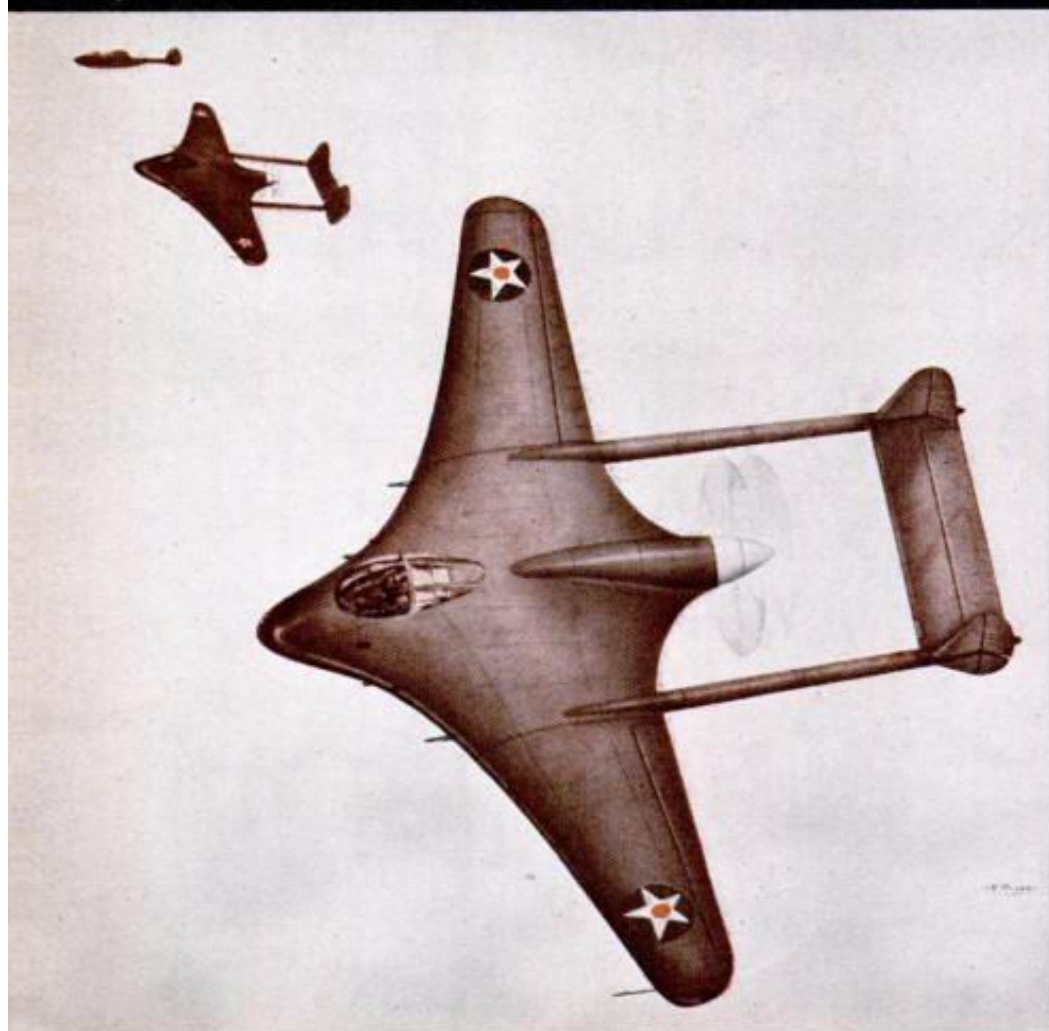
The first mobile crime laboratory in police history, a 29-foot bus with a revolving gun turret, soon will be ready to carry Illinois State Police to the scene of any major crime. Men in the turret will operate searchlights, a machine gun, and a motion-picture camera. Equipment will include a speedboat, diving helmets, asbestos suits, a lie detector, X-ray machines, fingerprinting and moulage rooms, darkroom and chemical laboratories, pulmotor with oxygen tanks, cutting torches, and a first-aid room with cots. Police will be able to question suspects and analyze clues.

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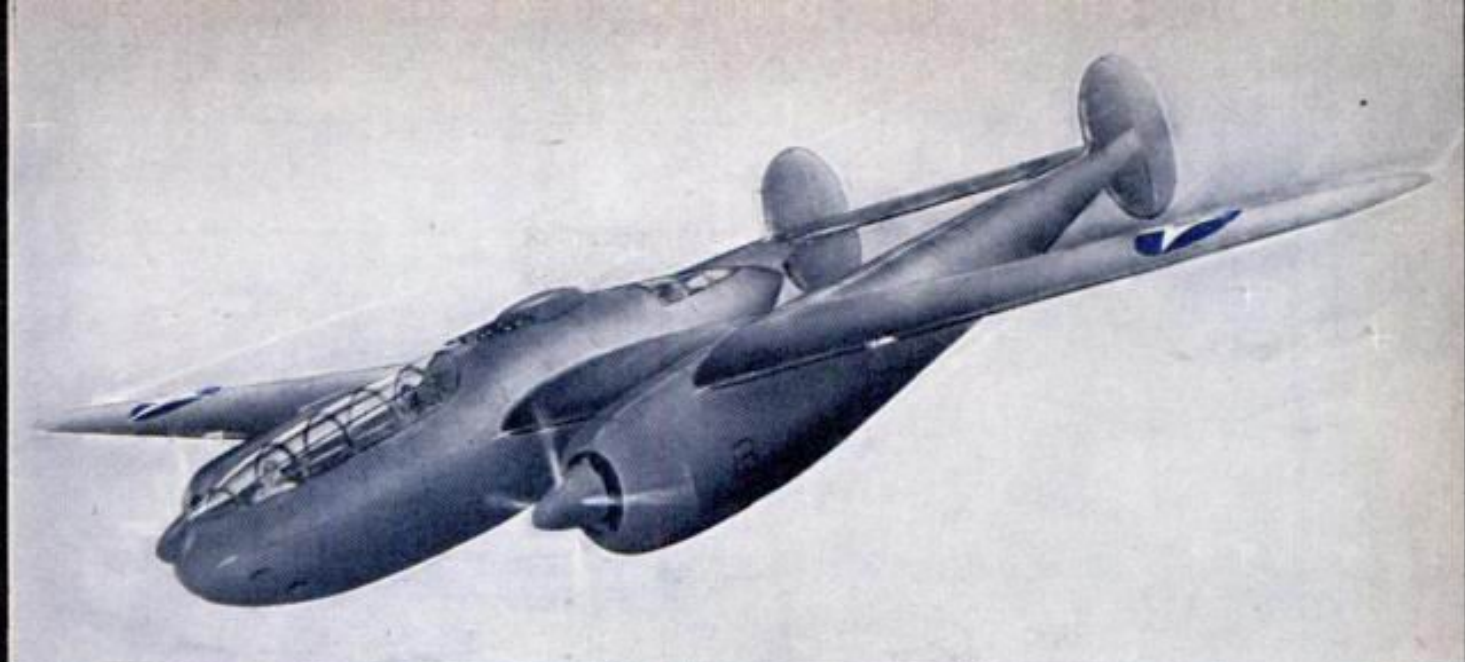
Drawing by
STEWART ROUSE



A FOUR-ENGINE BOMBER of the future conceived by design engineers of the U. S. Army Air Corps' Aircraft Laboratory at Wright Field, Dayton, Ohio, gains added fire power by using pusher-type propellers on its outer engines, leaving the front ends of the nacelles clear for guns



"THE BAT" suggests the experimental "flying wing." Its single engine, driving contra-rotating pusher propellers, is submerged in the enlarged center of the wing, which also accommodates the cockpit. Twin booms support the broad tail assembly



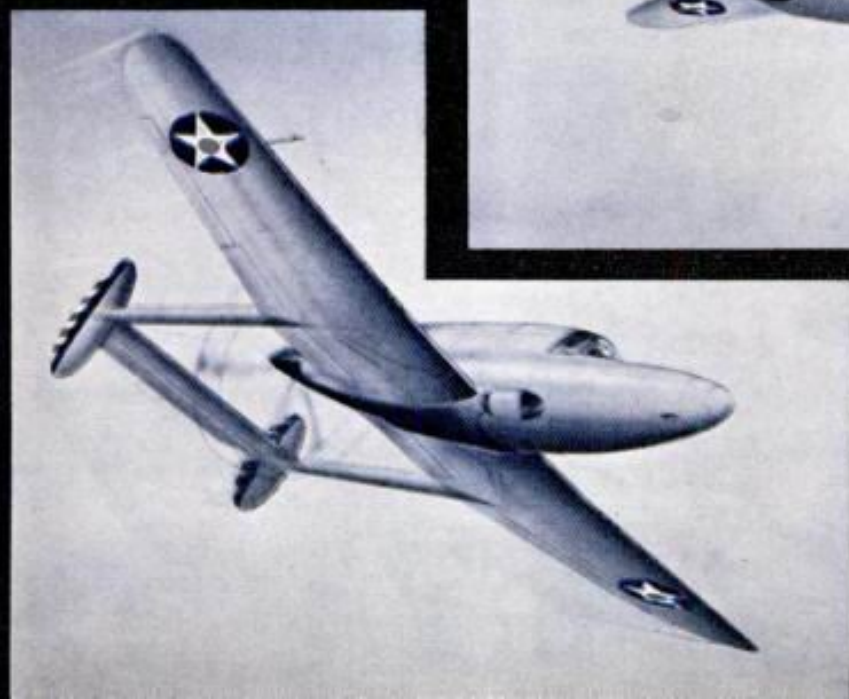
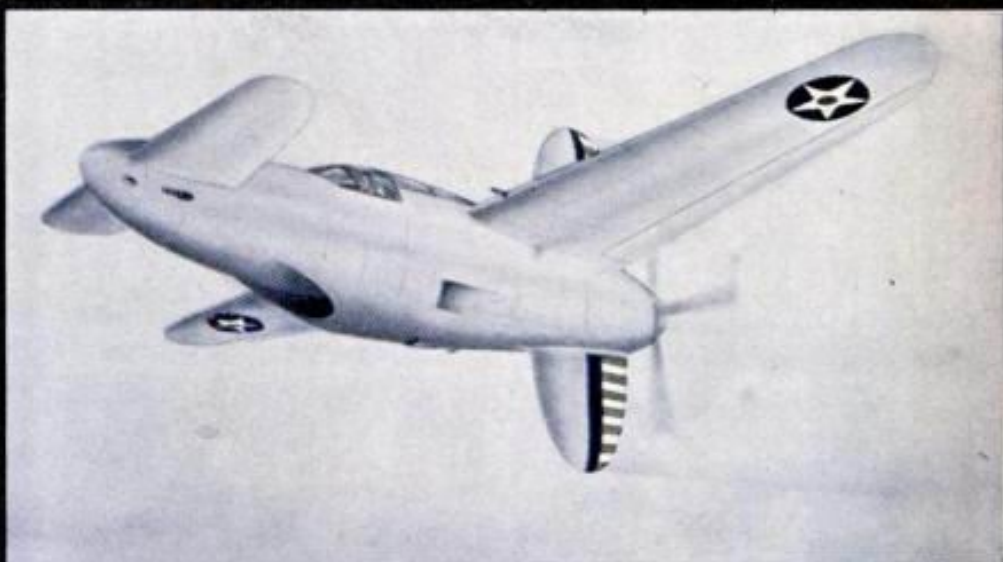
"THE SHRIKE" gets concentrated fire fore and aft, with a design somewhat like that of the P-38 of today

The Air Corps Looks Ahead

WITHIN the Army Air Corps Materiel Division at Wright Field, Dayton, Ohio, a group of young Air Corps officers and civilian engineers are designing planes of greater speed, power, and maneuverability than any we have today. Although

dubbed the "Buck Rogers Department," these men base their radical designs on actual experience in aeronautics. Most noticeable in this Design and Development Unit is the trend toward pusher-type planes, said to have a greater speed of climb.

"THE CANARD" (at right) seems to be flying backward, as its tail is in front and its propeller at the rear. This novel arrangement is said to eliminate rough air above the plane, and to give the pilot excellent vision



"THE SNIPE" (at left) has its single engine completely submerged in the fuselage behind the pilot, driving contra-rotating twin pusher propellers. Vision characteristics are specially good in this pursuit ship. All these designs represent trends being explored at the Dayton laboratory, many of them paralleling similar developments in Europe



1909 Early successful Avros were small, flimsy triplanes. This had a motorcycle engine and a four-bladed propeller



1912 Three years later, this test cabin monoplane was powered by a radial engine and had new wing mounting



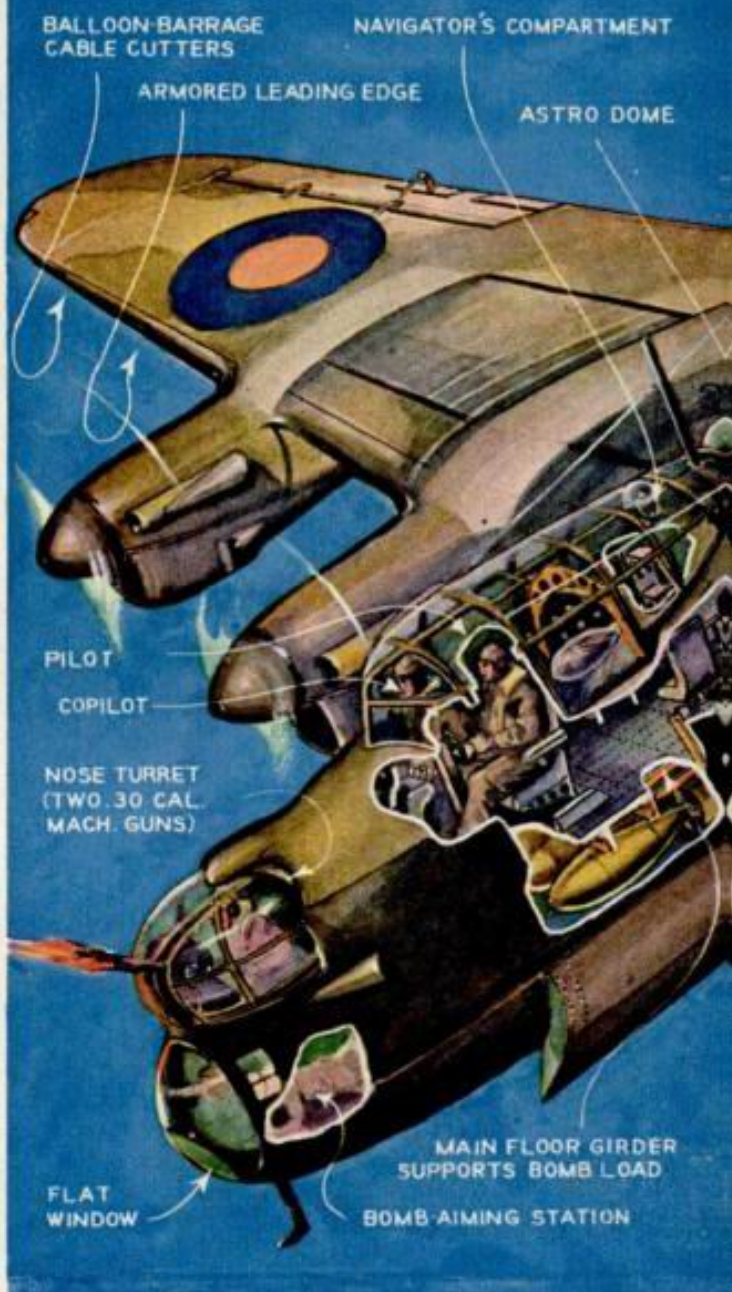
1914 The Avro 504-K was equipped with an 80 or 100-hp. rotary engine. It was a standard trainer for nearly a decade



1916 First Avro twin-motor heavy bombers were the Pike and Manchester, forerunners of the Lancaster shown right

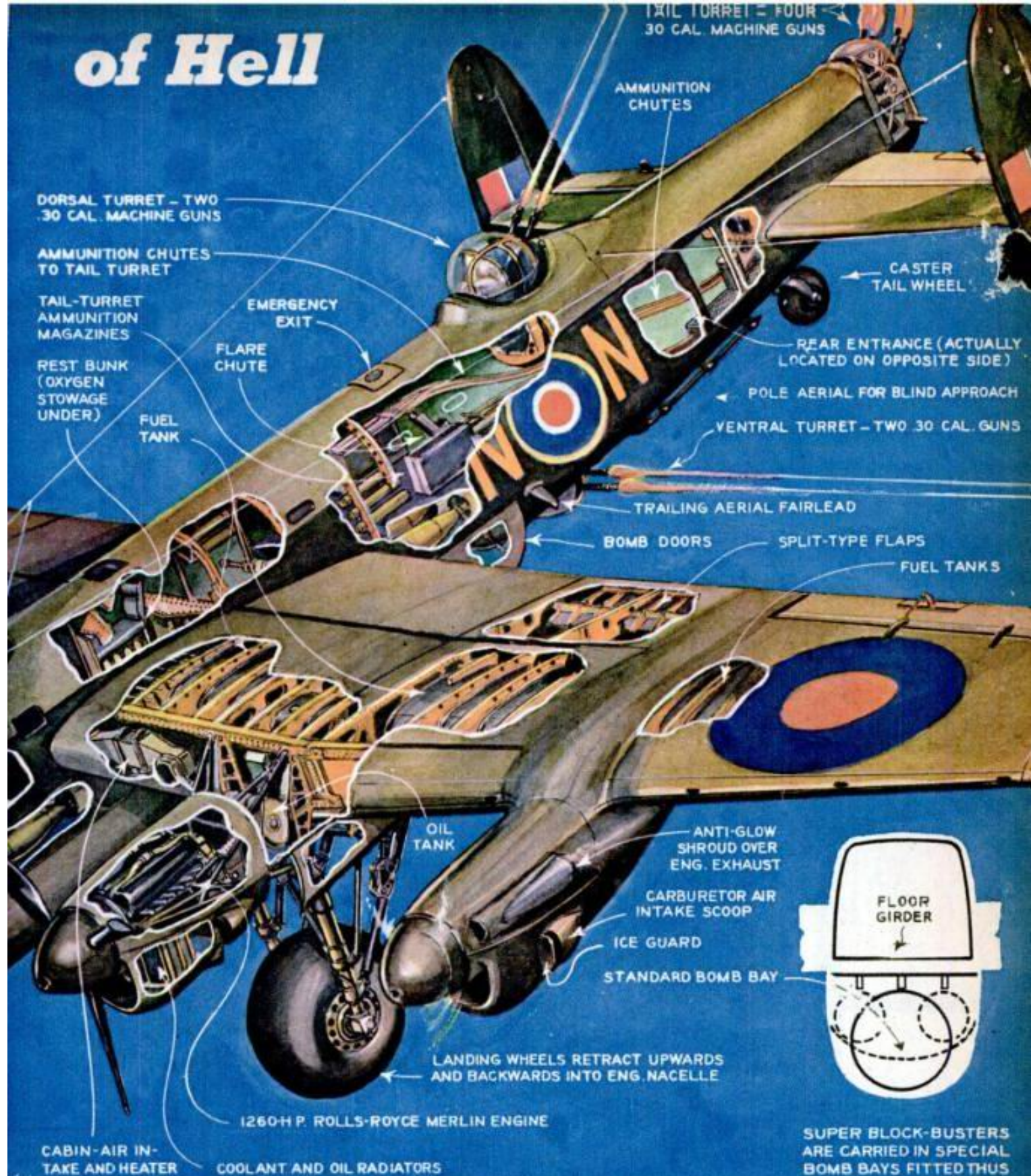
Eight Tons

BRITAIN'S GREAT LANCASTER
BOMBER COMES FROM A LINE
OF FAMOUS PLANES



BACKBONE of the hard-hitting British Bomber Command is the Avro Lancaster, the great ship that has been dumping truck loads of hell on Berlin and other Nazi points with pleasing regularity. Her eighteen bomb capacity includes accommodations for "cookies"—British term for blockbusters—and a variety of incendiary bombs, and she packs 10 medium-caliber machine guns in her four power-operated turrets for shooting off interference by German fighter

of Hell



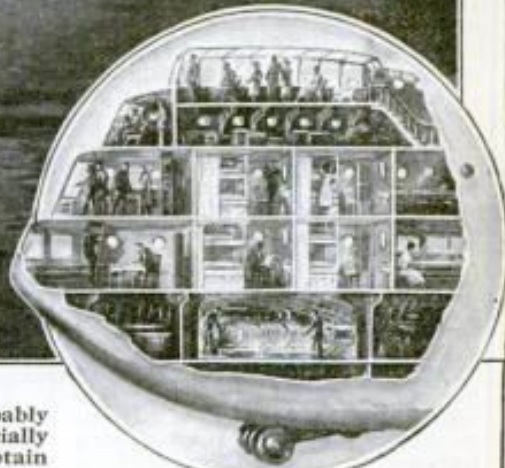
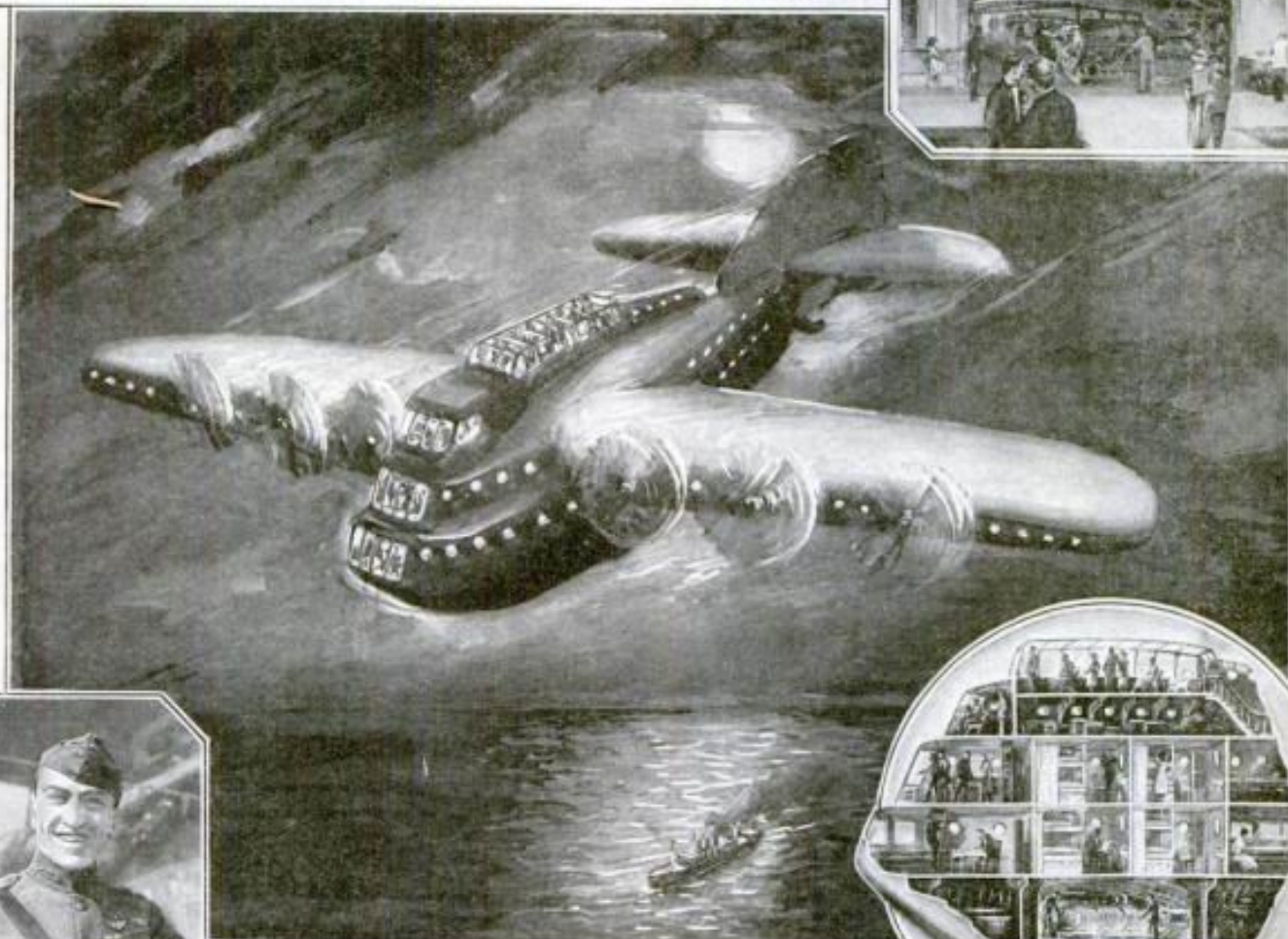
planes. Behind the Lancaster design lie nearly 40 years of successful airplane construction by a distinguished firm. The first Avro plane to leave the ground was a biplane which, in 1906, was the first of all British-built planes to fly. The name Avro is derived from the pioneer builder and pilot responsible for this first plane—A. V. Roe, now Sir Allison V. Roe.

A comparison of the full-color cut-away

above with the paintings at the left provides an interesting commentary on the rapid development of Avro design between the 9-hp. triplane model dated 1909, and the 5,000-hp. four-motored bomber of the present year. Best known to the flyers of World War I was the versatile model 504-K, in which probably more war flyers were trained than in any other single design of ship, not excepting our own "Jenny."

The Future Airliner

as Pictured by
Eddie Rickenbacker



Top—Interior of the airliner, showing motors in wing. Above—Arrangement of cabins, state-rooms, pilot house and observation deck in the nose



Captain Eddie Rickenbacker, who sponsors the design

© Popular Science Publishing Co., Inc.

THE commercial airliner of the future will probably resemble closely the airplane pictured here, especially if intended for supermarine travel," writes Captain Rickenbacker, first American ace during the war and now head of his own motor-car company.

"Radical as the design may seem, it will be observed that in its essentials—in cantilever wings, hull profile, retractable chassis—the airplane is simply an embodiment of engineering practices already sanctioned in America and abroad."

This superliner of the skies, for passenger and freight transportation, which Captain Rickenbacker predicts will be realized "with the passing of but a very few years," will be a giant monoplane, perhaps 300 feet from wing tip to wing tip.

The motors will be of approximately 1000 horsepower each, several motors to a unit, and each unit driving a great propeller with three blades from 15 to 20 feet long. The motor units will be set in the wings, which will be very thick—from five to 10 feet on

the leading edge—and will be of internally braced cantilever construction.

The fuselage will be in the form of a boat, but landing wheels that draw into the body during flight will also be provided. This will enable it to alight on land and water.

Have You Considered Aviation as a Career?

By Glenn H. Curtiss

America's Foremost Airplane
Manufacturer

WHERE are the young men who are going to make brilliant aerial careers for themselves in the next few years? Whose will be the names written large on the sky, in terms of fame and financial success, when the great boom of commercial flying comes?

Will you be among them? You may not realize how enticing a future aviation holds for the young fellow today looking about for an active,



Glenn H. Curtiss

adventurous career. But remember that while commercial flying has been suffering depression recently, just like all other businesses, the leading aeronautical companies expect an inevitable

expansion within three years. And when it comes, the greatest need will be, not for planes, routes, or landing fields, but for trained men. Boys now in high school and college will become the pilots and mechanics, and when the expanding industry requires executives and salesmen, they will be drawn from the practical fliers and mechanics, who know the business of aviation from the air down.

If you are looking about you for an occupation, the profession of aviation offers opportunities that seem almost unlimited.

Up to the present time most of the men employed by the commercial aircraft companies were aviators trained in the war; but war training is becoming less necessary and less desirable. At the front, the successful pilot was the man who took the most risks. If he broke his plane, the army gave him another. Because it was necessary to take many chances, a war-trained pilot has a tendency to believe that a certain amount of stunt flying is part of a good pilot's job.

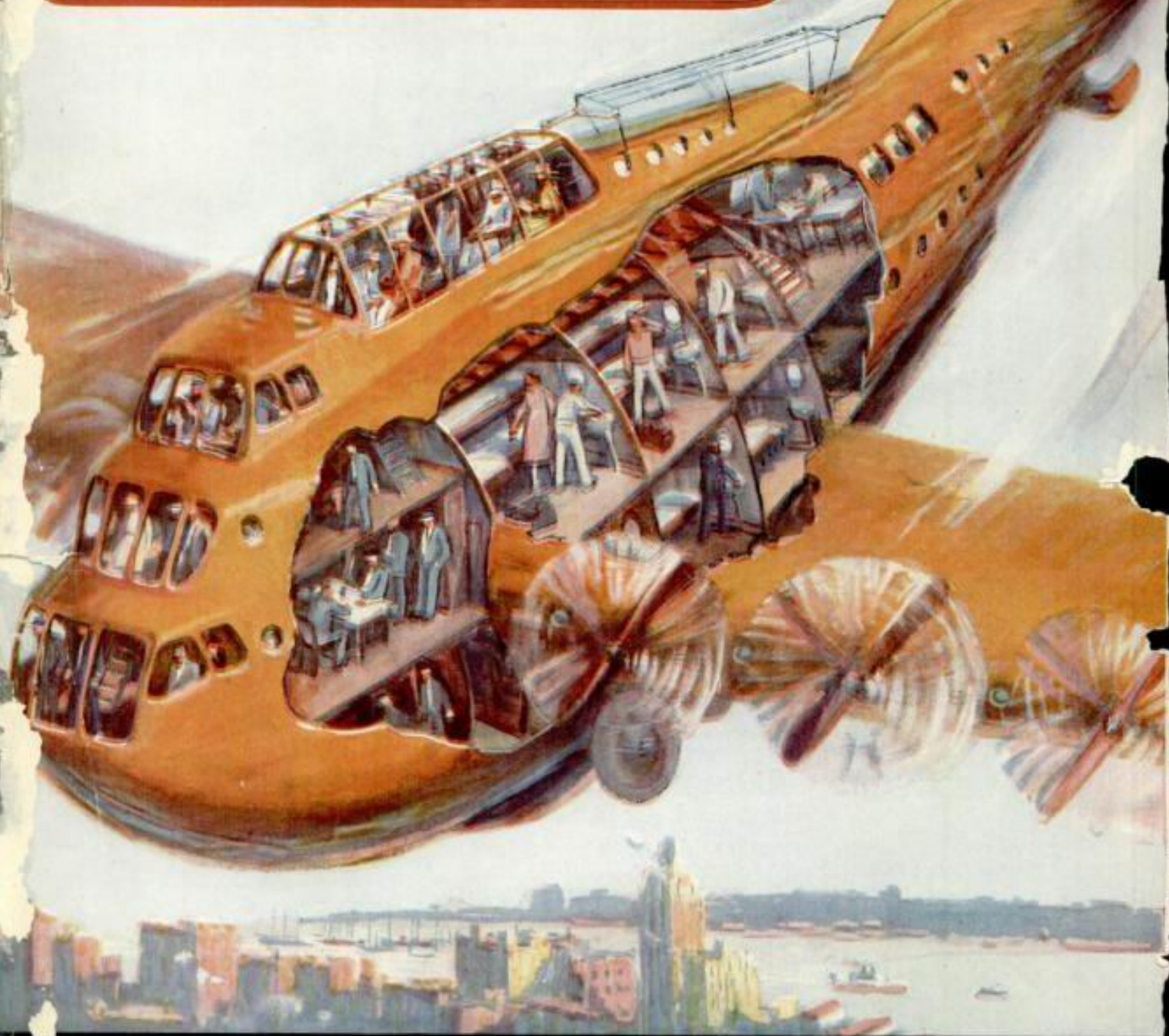
The commercial companies think differently. Nowadays, a pilot who does reckless stunts is warned the first time and fired the second; for, above everything else, profitable operation demands men trained

JACK BINNS' **RADIO** DEPARTMENT

Reg. U.S. Pat. & Off.

Popular Science

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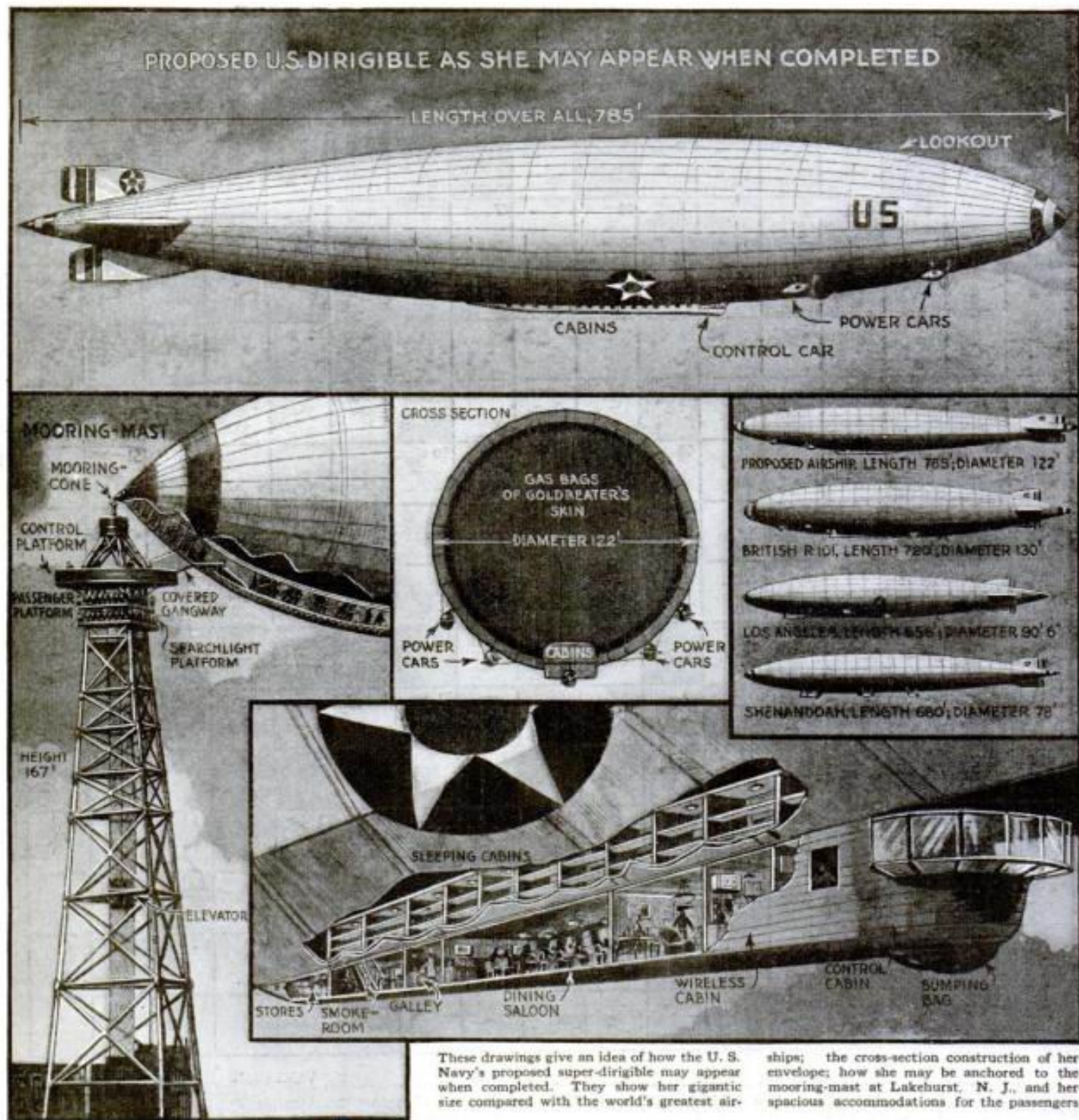


Eddie Rickenbacker Predicts Huge Passenger Airplane—(See page 35)

**In This Issue: Herbert Hoover, Henry Ford,
Glenn Curtiss, Charles P. Steinmetz**

JULY

25 CENTS



U. S. Plans the Greatest Airship of All

DWARFING the giant proportions of the *Los Angeles* and the *Shenandoah*, and even the two great dirigibles ordered by Great Britain, is an air-liner proposed recently by United States naval experts. It would be by far the largest airship in the world.

With a capacity of 6,000,000 cubic feet, nearly three times that of either of the American dirigibles and 1,000,000 cubic feet more than the British ones, it could be used for regular transatlantic trips. It would carry 80 passengers on a voyage and at least 32 tons of mail and freight. Counting on 40 round trips a year between New York and London, it is estimated that the leviathan would make a net yearly profit for the United States

Government of approximately \$5,000,000.

In design the air-liner differs radically in several ways from any others previously built. The R-100 and the R-101, the two ships that the British are planning for passenger service between England and India in 1927, are to use hydrogen in their gas bags. But while hydrogen has greater lifting capacity, United States officials favor helium on account of its safety.

By using hydrogen in conjunction with helium, the advantages of both may be retained, and this combination is included in plans for the proposed American dirigible. Hydrogen would be used for the inner gas space, surrounded by a layer of helium that would act as a protector from fire.

The cabin, which for passenger service would contain luxuries comparable to those of ocean liners, would extend nearly half the length of the ship.

Ordinarily the ship would operate from mooring-masts. The one at Lakehurst, N. J., which is 167 feet high, could be used, but others of greater height would have to be erected. For repairs, a shed of huge dimensions would be necessary.

A dirigible with 10,000,000 cubic feet capacity, according to experts, would be capable of making non-stop flights around the world.

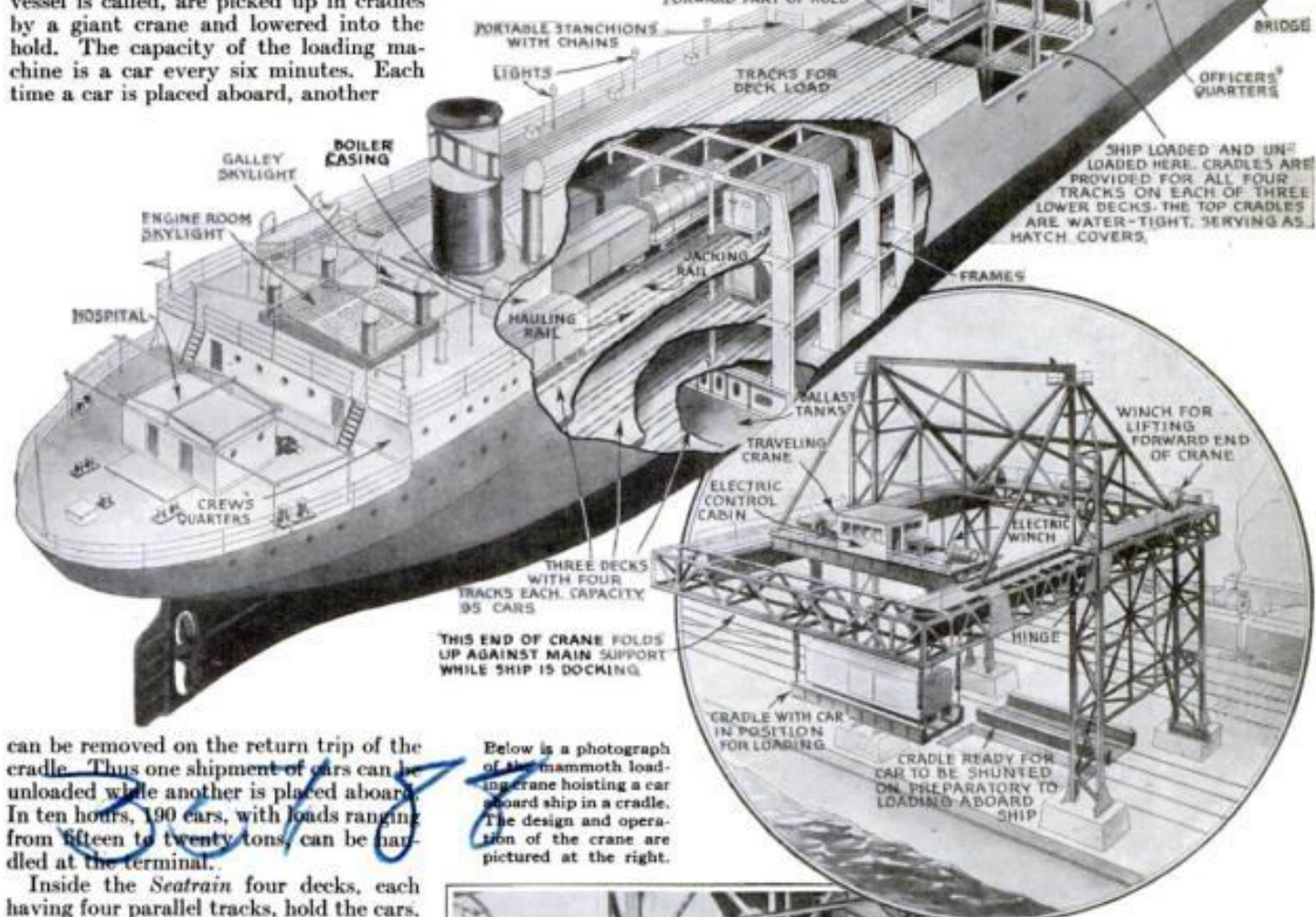
Rear-Admiral William A. Moffett, Chief of the Bureau of Naval Aeronautics, estimates the cost of the proposed air-liner at \$6,000,000.

Steamer Carries a Mile of Cars

Loaded Freight Train, Hoisted Aboard by a Mammoth Crane, Is Swallowed by Ocean Ferryboat

A LOADED train almost a mile long disappears into the hold of a monster ocean ferryboat, two thirds the size of the liner *Mauritania*, which recently began operating between New Orleans, La., and Havana, Cuba. The freight cars, hauled to the dock alongside the *Seatrain*, as the vessel is called, are picked up in cradles by a giant crane and lowered into the hold. The capacity of the loading machine is a car every six minutes. Each time a car is placed aboard, another

How freight cars are loaded and distributed on tracks in the hold and decks of the *Seatrain*. Inset shows method of locking the cars in place.

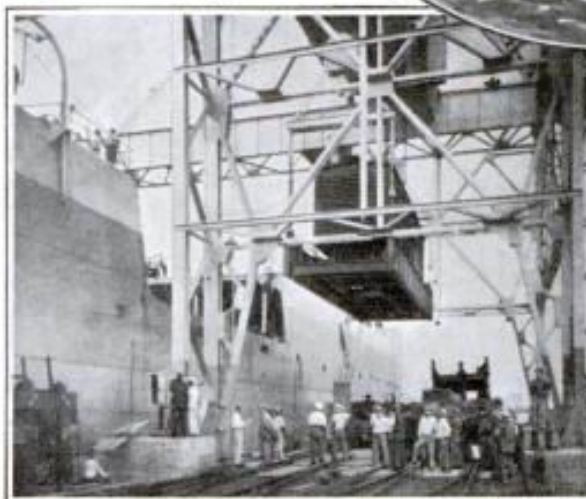


can be removed on the return trip of the cradle. Thus one shipment of cars can be unloaded while another is placed aboard. In ten hours, 190 cars, with loads ranging from fifteen to twenty tons, can be handled at the terminal.

Inside the *Seatrain* four decks, each having four parallel tracks, hold the cars. The capacity of the ship is ninety-five cars, virtually a train a mile long. They are distributed in such a manner as to provide the best balance during the voyage. Twenty-six are placed in the hold, twenty-six on the second deck, thirty on the upper deck, and thirteen lightly-loaded cars on the superstructure. When they are lowered into the hold to the level of the track, a mechanical puller draws them into place. To prevent the cars from rolling or tipping in heavy seas, the wheels are braced at each end by special bumpers, while steel arms, locked against the side of the cars, prevent them from rocking.

This Leviathan of ferries was built in Scotland at a cost of about \$700,000. Its length is 427 feet six inches; its width

Below is a photograph of the mammoth loading crane hoisting a car aboard ship in a cradle. The design and operation of the crane are pictured at the right.



sixty-two feet three inches. Its steam engines, burning oil fuel, develop 3,000 horsepower and drive the single-screw vessel at a service speed of eleven knots an hour.

The new *Seatrain* service allows freight to be loaded in cars at factories in American cities located at a distance from the sea and sealed until it reaches its destination in Cuba. It saves the expense of handling and rehandling the contents of freight cars at the steamship piers and protects the packages from breakage and pilfering.

New Flying Field for Roof Tops

HIGH officials of the U. S. Navy and representatives of the French and English governments recently witnessed a demonstration in Brooklyn, N. Y., of a remarkable new airplane landing and launching device—a tilting platform which, according to its inventor, R. James Gibbons, a member of the advisory board of the Guggenheim School of Aeronautics, New York University, will revolutionize landing fields. It will enable a plane, he says, to land or take off in as small a space as the roof of a skyscraper in a crowded business section—the incline serving to halt a plane when landing, or to speed its take-off when departing.

On this page our artist has pictured in detail the construction and operation of the novel device, of which Gibbons exhibited a working model to the experts.

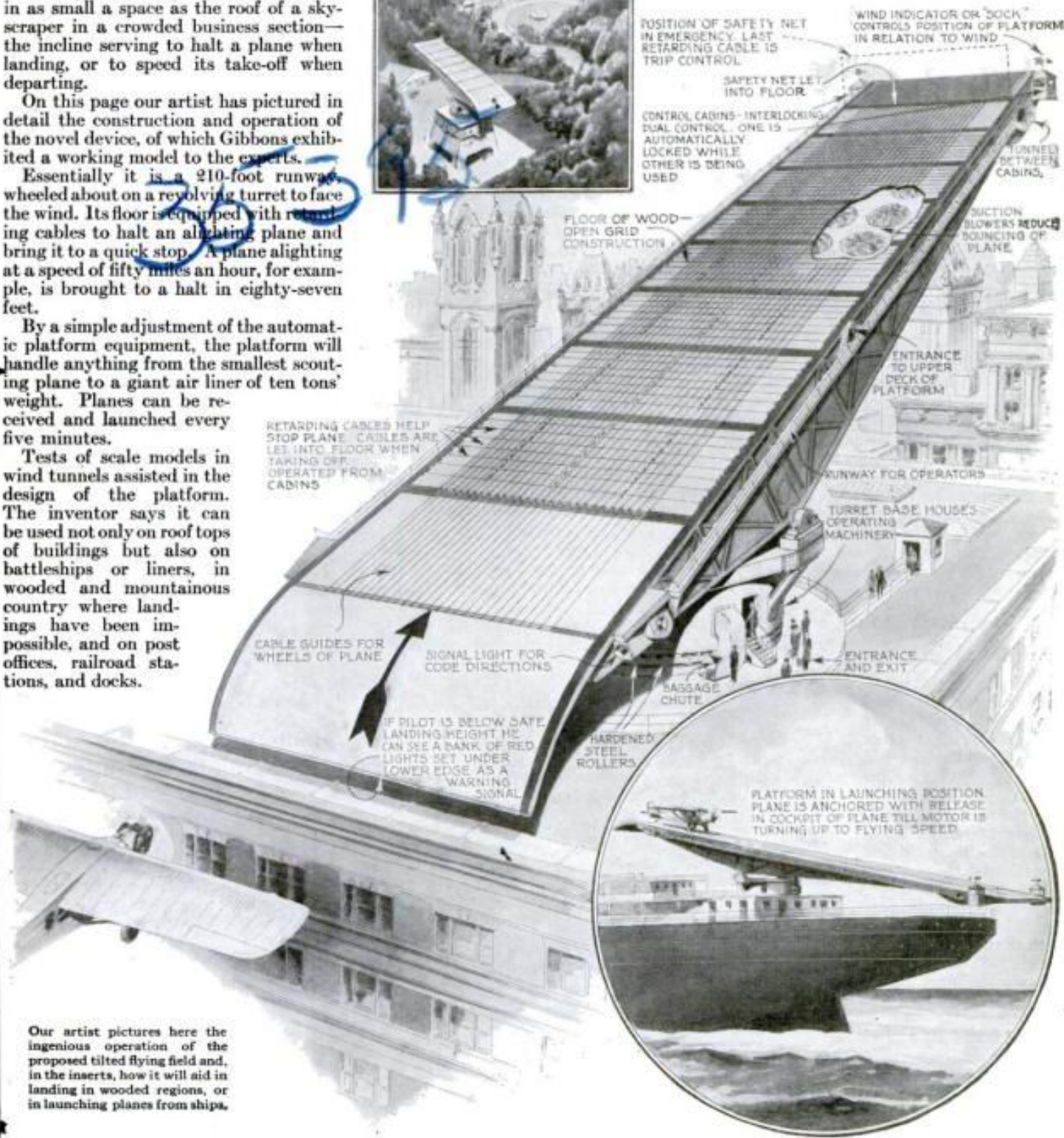
Essentially it is a 210-foot runway, wheeled about on a revolving turret to face the wind. Its floor is equipped with retarding cables to halt an alighting plane and bring it to a quick stop. A plane alighting at a speed of fifty miles an hour, for example, is brought to a halt in eighty-seven feet.

By a simple adjustment of the automatic platform equipment, the platform will handle anything from the smallest scouting plane to a giant air liner of ten tons' weight. Planes can be received and launched every five minutes.

Tests of scale models in wind tunnels assisted in the design of the platform. The inventor says it can be used not only on roof tops of buildings but also on battleships or liners, in wooded and mountainous country where landings have been impossible, and on post offices, railroad stations, and docks.



Aviation expert invents a tilting platform to halt planes in small space on skyscrapers, steamers, or docks. May revolutionize construction of airports.



Our artist pictures here the ingenious operation of the proposed tilted flying field and, in the inserts, how it will aid in landing in wooded regions, or in launching planes from ships.

Drawn especially for POPULAR SCIENCE MONTHLY by B. G. Seielstad

One Man Could Run This Ship!

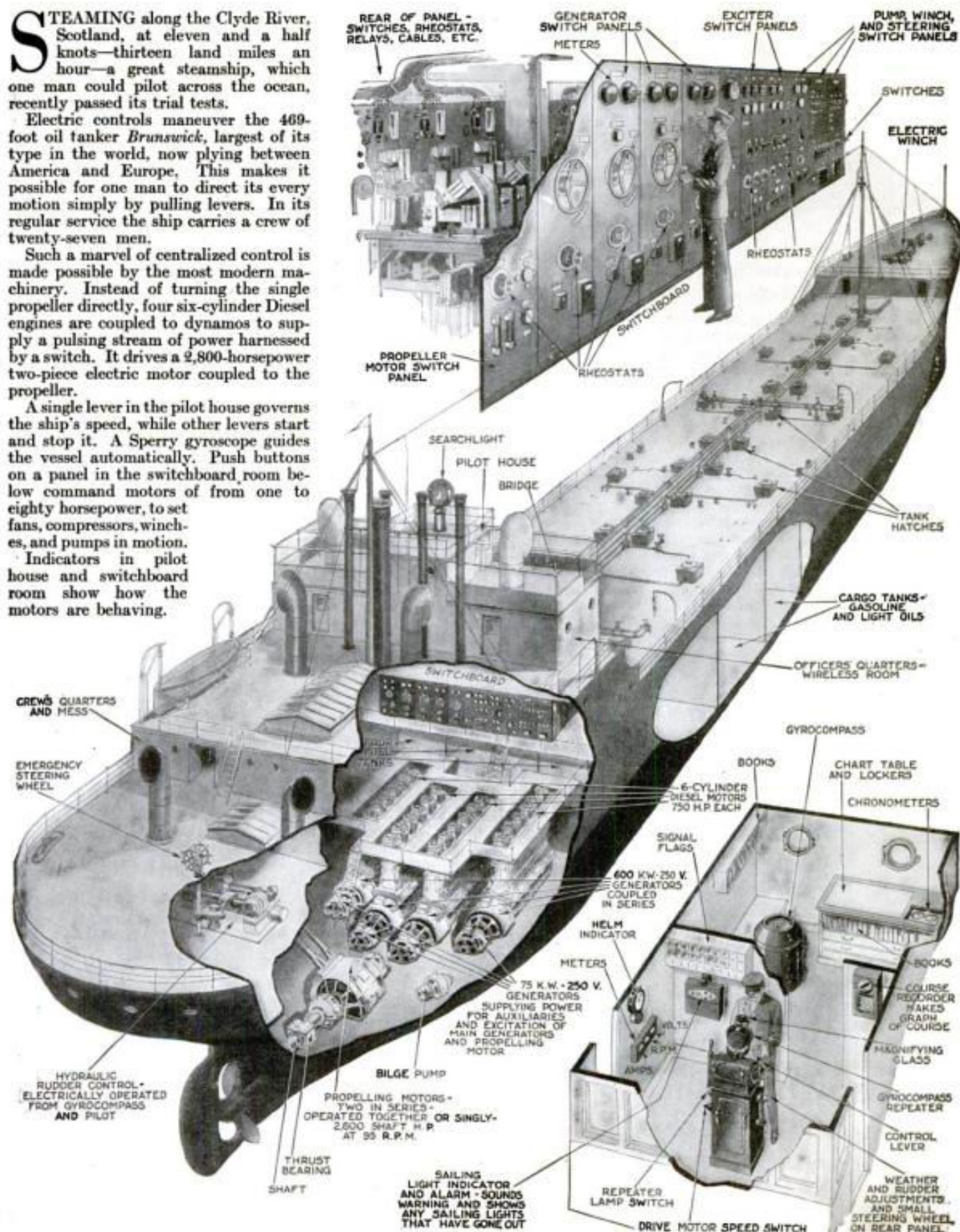
STEAMING along the Clyde River, Scotland, at eleven and a half knots—thirteen land miles an hour—a great steamship, which one man could pilot across the ocean, recently passed its trial tests.

Electric controls maneuver the 469-foot oil tanker *Brunswick*, largest of its type in the world, now plying between America and Europe. This makes it possible for one man to direct its every motion simply by pulling levers. In its regular service the ship carries a crew of twenty-seven men.

Such a marvel of centralized control is made possible by the most modern machinery. Instead of turning the single propeller directly, four six-cylinder Diesel engines are coupled to dynamos to supply a pulsing stream of power harnessed by a switch. It drives a 2,800-horsepower two-piece electric motor coupled to the propeller.

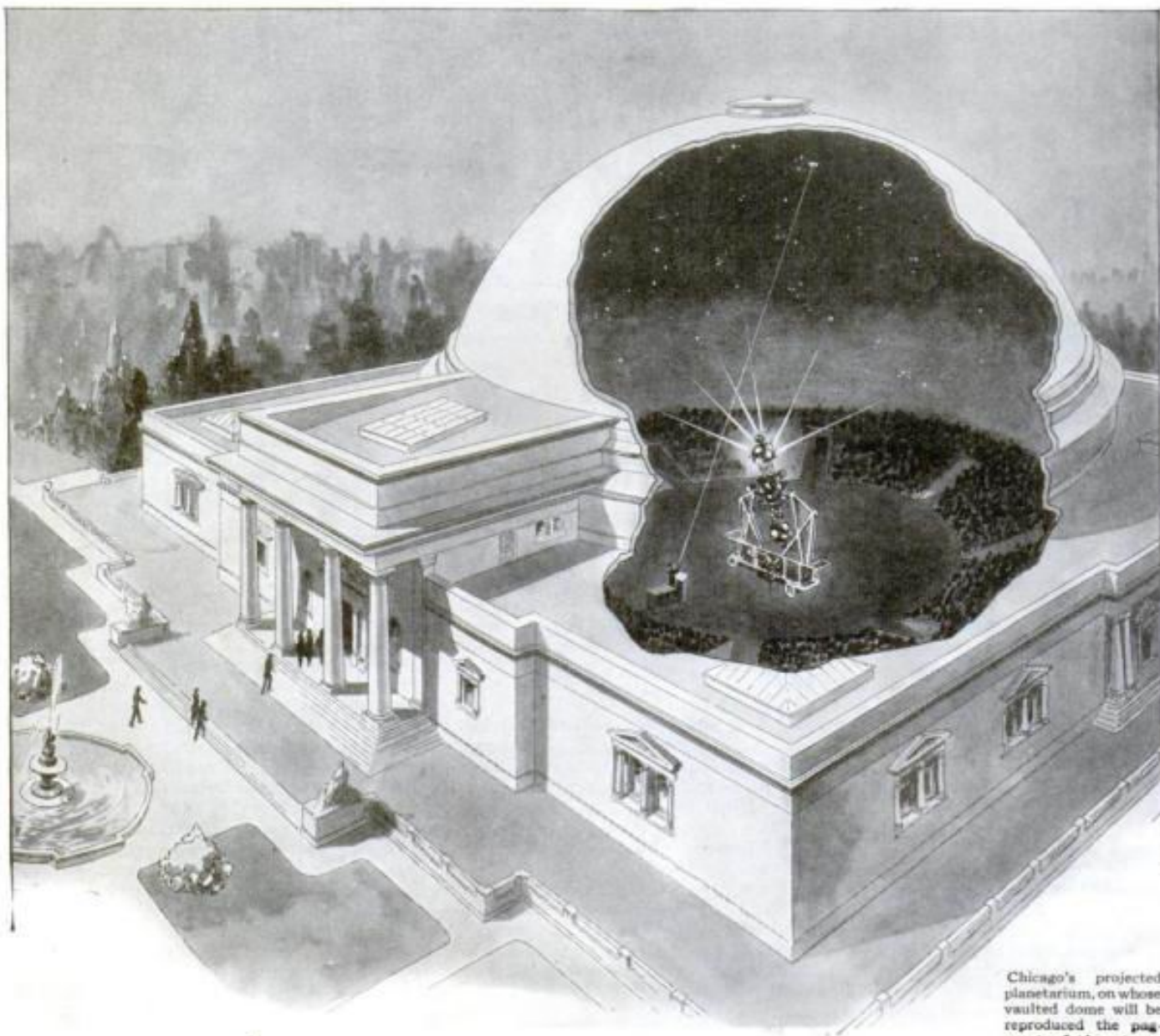
A single lever in the pilot house governs the ship's speed, while other levers start and stop it. A Sperry gyroscope guides the vessel automatically. Push buttons on a panel in the switchboard room below command motors of from one to eighty horsepower, to set fans, compressors, winches, and pumps in motion.

Indicators in pilot house and switchboard room show how the motors are behaving.



These broken-away views of the huge new oil tanker *Brunswick*, her switchboard room (top), and pilot house (right), reveal the improved electrical and mechanical features which give her remarkable simplicity of control and flexibility of operation. The ship's speed is governed by a single control lever in the pilot house, and all movements directed by levers and switches.

Half a Billion New Stars!



Chicago's projected planetarium, on whose vaulted dome will be reproduced the pageant of the stars.

Greatest Telescope, to Enlarge the Universe Eight Times, and Marvelous "Sky-Theater" Promise Untold Thrills in Astronomy

By EDWIN W. TEALE

ON A California mountain top, a few years hence, there will take place one of the great adventures of all time. A man will look into the night sky and his gaze will penetrate beyond the most distant stars within the range of ordinary telescopes, past the lonely "island universes" revealed by the giant 100-inch Hooker instrument at Mt. Wilson Observatory, beyond the last confines of man's knowledge of the heavens, at least *four times* farther than any man has ever seen before!

This has just been made possible by a gift of the International Education Board

to the California Institute of Technology, at Pasadena, for the purpose of building a 200-inch reflector telescope, twice the size of the largest now in existence. This monster eye is expected to multiply many times the sphere of our observation of the heavens and may show us half a billion nameless stars that lie outside the range of our best modern telescopes.

The delicate work of casting the fused-quartz disk for the great mirror, nearly seventeen feet across, will begin within a few months and the finished instrument is expected to be in use within three years.

The magnitude of this undertaking can be appreciated when we are told that this mirror disk alone will weigh thirty tons—as much as fifteen good sized automobiles!

Heretofore the chief disadvantage of the reflector type telescope has been its sensitiveness to changing temperatures. Even a slight change in the room temperature is sufficient to expand or contract the glass of the Mt. Wilson giant the infinitesimal fraction of an inch sufficient to distort the image of a heavenly body under observation.

In the proposed super-telescope, this



Plan of world's largest telescope, whose 200-inch reflector will enable astronomers to peer four times farther than ever before.

difficulty, it is believed, will be overcome by the use of fused quartz in place of glass. It is relatively unaffected by temperature changes—a characteristic which may enable astronomers to study the sun directly, a thing never before possible with a reflector, and to discover new secrets of this great solar heating plant which continually pours energy upon the earth at a rate estimated at a horsepower for every square yard it shines upon.

IF YOU, a few years hence, should look through the new super-telescope, which will be similar in design to the Hooker instrument, the first thing that would surprise you probably would be the position of the eyepiece. Instead of being at the end, as in the familiar "spyglass," it will be at the side. To see a star, you would look at right angles to the cylinder of the instrument trained on the heavens. The huge, dish-shaped mirror will be situated at the lower end of the cylinder. It will catch rays of light from a distant star and concentrate them at a point near the

opposite end. At this point, a plane mirror will catch the light directed to it by the main mirror and will be tilted to direct the light at right angles into the eyepiece.

What the penetrating eye of the monster telescope will discover can only be conjectured. Mysteries are locked in almost every glittering pin point of light that marks the position of a star on a winter night. Take that unassuming little star that trails along behind Sirius, the brightest star in our heavens. It seemed to offer little interest until recently astronomers, with their sensitive instruments, weighed it and discovered that it is the

densest star in the sky. A cubic inch of this star, they tell us, weighs more than a ton! On the other hand,

Saturn has a specific gravity so low it would float in water, bobbing up and down like a rubber ball if it fell into an ocean large enough to contain it!

In one spot in the sky, so small to our eyes that it would not make a visible speck on the face of the moon, a cluster, in the constellation Hercules, contains more stars than are visible to the naked eye in both the northern and southern hemispheres! Opposed to this is "the darkest place in the sky," a black, pear-shaped spot

(Continued on page 129)

The Tallest by Fifteen Stories

CONSTRUCTION soon will begin on what will be the world's largest and tallest building—the Chicago Tower and Apparel Manufacturers' Mart. Seventy-five stories high and covering two city blocks, it will house in addition to offices and stores, a 440-room hotel, a 1,024-car garage, two clubs, a hospital, swimming pools, gymnasiums, and even a small golf course.

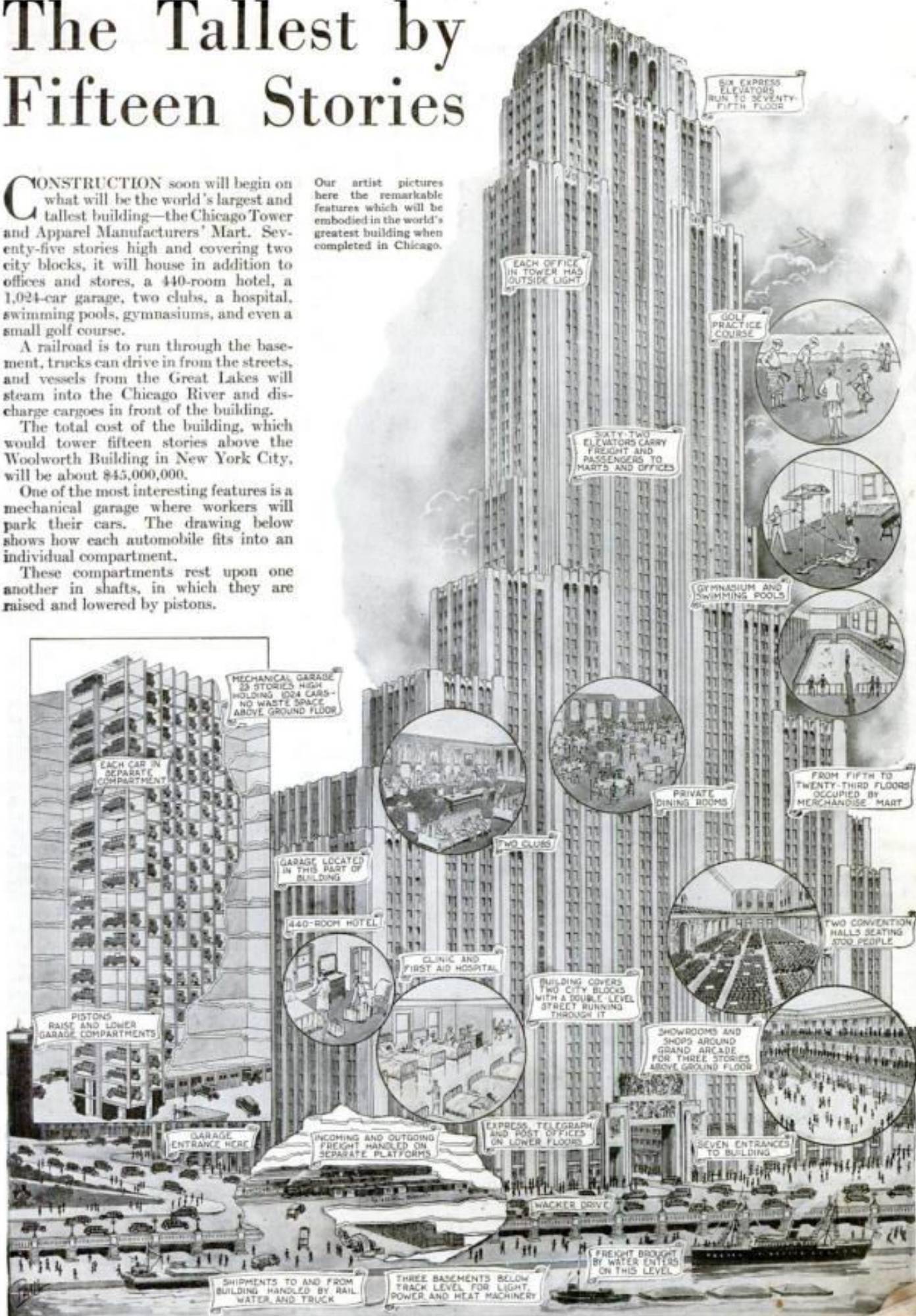
A railroad is to run through the basement, trucks can drive in from the streets, and vessels from the Great Lakes will steam into the Chicago River and discharge cargoes in front of the building.

The total cost of the building, which would tower fifteen stories above the Woolworth Building in New York City, will be about \$45,000,000.

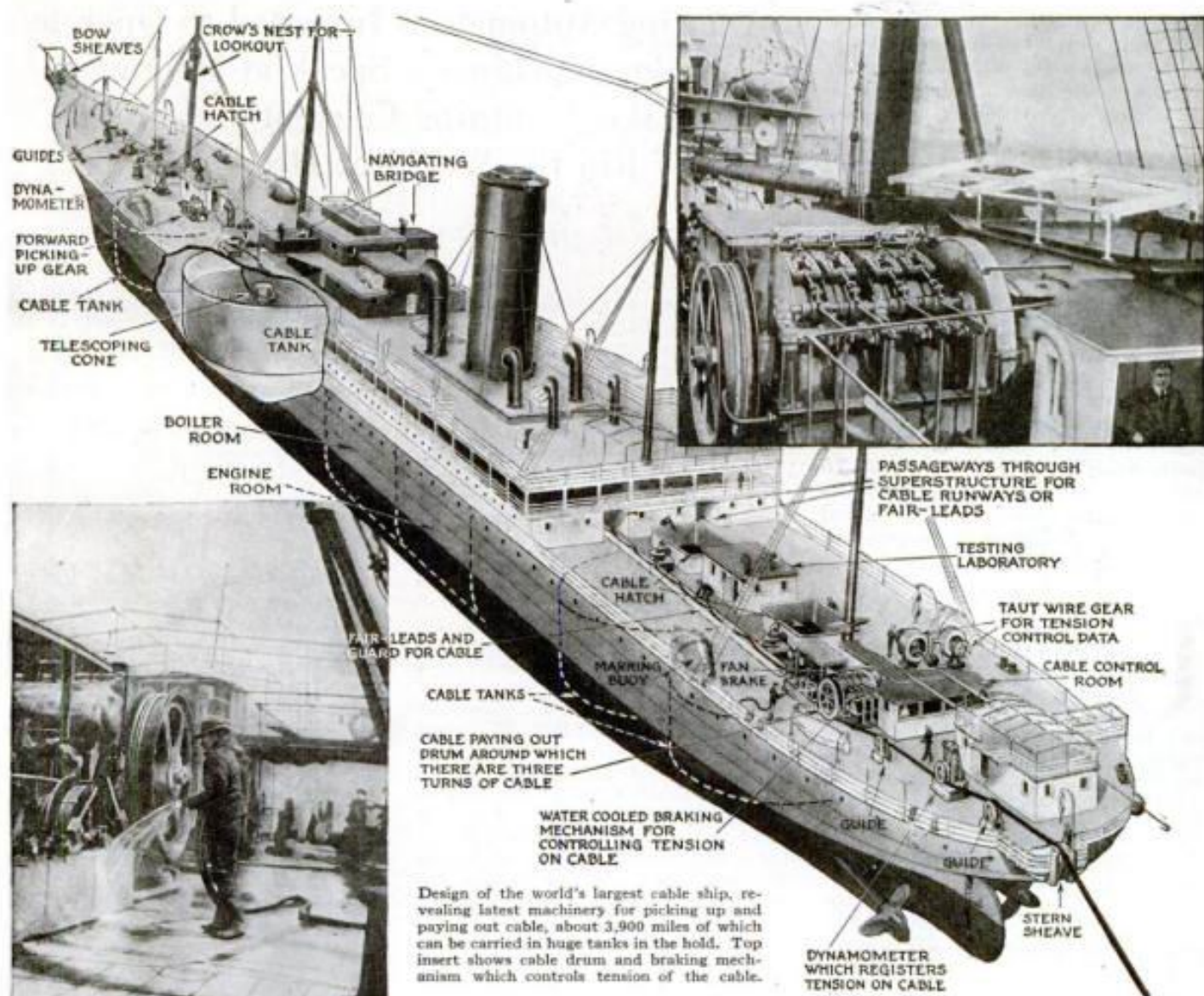
One of the most interesting features is a mechanical garage where workers will park their cars. The drawing below shows how each automobile fits into an individual compartment.

These compartments rest upon one another in shafts, in which they are raised and lowered by pistons.

Our artist pictures here the remarkable features which will be embodied in the world's greatest building when completed in Chicago.



Laying the New Ocean Cable



Design of the world's largest cable ship, revealing latest machinery for picking up and paying out cable, about 3,900 miles of which can be carried in huge tanks in the hold. Top insert shows cable drum and braking mechanism which controls tension of the cable.

Four friction brakes, acting directly on the paying-out drum, are cooled by water.

How the World's Greatest Cable Ship Joins the Continents with Miles of Unbroken Wire

THE largest and fastest cable-laying ship in the world, the *Dominia*, recently completed the main link—between Bay Roberts, Newfoundland, and the Azores—of the latest trans-Atlantic cable, which will transmit eight messages at once between the United States, Europe, and Africa. The *Dominia* is 509 feet long, twenty-two feet longer than the *Colonia*, its famous sister ship, which has laid more miles of cable than any other vessel in the world. Its oil-burning engines drive it at a top speed of 14.5 knots an hour. It has a crew of 130 men, and its 180,000 cubic feet of cable space allows it to carry approximately 3,900 miles of deep-sea cable.

Four huge tanks in the hold contain these miles of cable, all in one piece. During a trip, an electric current is kept passing from shore through the length of the cable, lighting a signal lamp. If the

lamp goes out, indicating a break or the development of a defect in the wire, the man on watch presses a button which instantly stops all machinery and the ship itself. Wheels and guides lead the cable from the hold to a drum, which it circles three times before continuing through a dynamometer, thence through a final sheave at the stern of the ship and into the ocean.

Through an ingenious system of brakes, the cable engineer governs the slack, which is allowed to take care of irregularities of the sea bottom. A chain connects the shaft of the drum with a fan which revolves in a metal case with adjustable openings that regulate the inrush of air, and consequently the speed at which the fan turns. The greater the pressure of in-rushing air, the slower the fan revolves. As it slows up, the chain drags on the shaft, slowing the drum. The fan's

maximum drag is equal to the pull of forty horses, but it has an air-cushion effect without sudden jerking that might part the cable.

BESIDES the fan brake, four friction brakes act directly on the shaft, which is cooled by a constant stream of water. A piano wire, played out with the cable, is kept taut and a comparison of the amounts of cable and wire that are let out shows the exact amount of slack in the cable. The dynamometer shows the stress on the cable in hundred-weights and indicates when the pull on it is nearing the danger point.

When the vessel is laying cable on the ocean's bed it plows ahead night and day at an average speed of seven knots an hour, leaving about two hundred miles of copper wire behind it during a twenty-four-hour run.

HUGE Flying Hotels Race For First Overseas Flight

By CARL HELM

FLASHING silver against the sun, the giant dirigible heads out to sea. A hundred people on her passenger list, and every cabin full!

On the streets below crowds strain their eyes and wave their farewells as the drone of the motors of the flying hotel recedes.

The "Queen of the Air" melts into a cloud. She is gone! Day after tomorrow, soon after dawn, she will arrive in London. Thirty-eight hours from New York to Europe—the fare is \$400.

That is no dream of the far distant future, for within a few months the trans-ocean passenger-carrying dirigible should be undergoing its great test. Two nations, England and Germany, are racing for the glory of sending the first air liner, with fourscore or more passengers, across the Atlantic to New York.

That feat accomplished, the dream of a cruise by air to Europe and back approaches actuality.

AERONAUTICAL authorities agree that when the dream comes true, it first will be through the development of the rigid airship. The airplane's capacity as a passenger carrier is necessarily limited by its type of construction, its fuel requirements, and the vagaries of weather. As a means of transportation it is to the dirigible as the speedboat is to the ocean liner; or, in the equation of comfortable travel, as a motorcycle to the Twentieth Century Limited.

At this writing it seems likely that the British air liner, *R-100*, the biggest air-

ship ever constructed, will be the first to cross the Atlantic. The U. S. Post Office Department is already looking to the use of her facilities. Comparison with her aquatic rivals is in order.

She is 709 feet long, forty-nine feet longer than the *Los Angeles* and a scant fifty feet less than the S. S. *Mauretania*. She is 133 feet in diameter, greater by thirty-three feet than the width of the *Leviathan* or the *Majestic*, the world's largest steamships. In weight, fully loaded, she is 166 tons. On her nose, she would come within eighty-three feet of the tip of the sixty-story Woolworth Building. She weighs six tons more than an express locomotive.

THE ship has thirty-nine cabins to accommodate her 100 passengers. A crew of forty mans her. She has a cruising radius of 4,000 miles and a speed of eighty-three miles an hour. She will carry ten tons of baggage, mail, and freight.

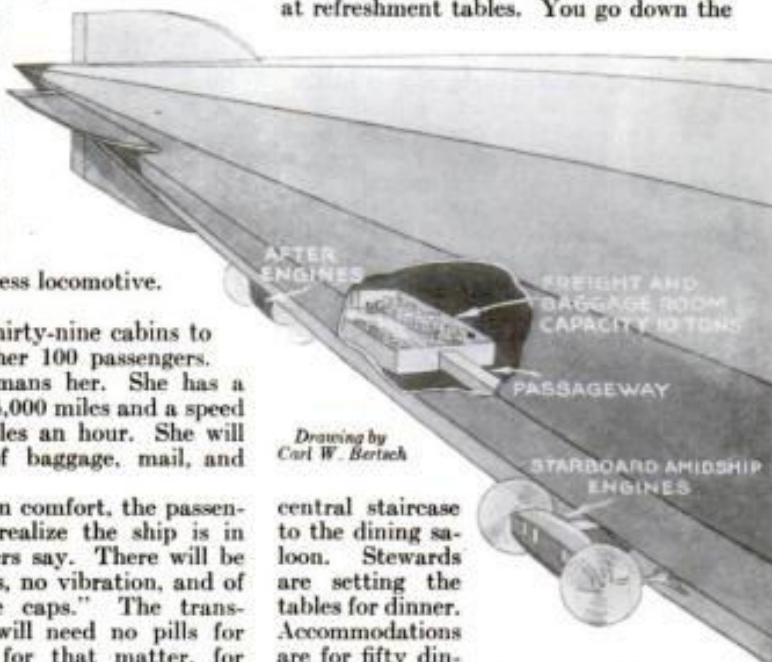
As for crossing in comfort, the passenger scarcely will realize the ship is in motion, her builders say. There will be no noise of engines, no vibration, and of course no "white caps." The trans-Atlantic voyager will need no pills for mal-de-mer, nor, for that matter, for mal-d'air!

Suppose you are on your first trip. You and your luggage have come up an elevator inside the towerlike mooring mast just outside New York. You enter from the mast through a door in the bow, and walk along a wide companionway in the hull of the ship to the passengers' saloon, about a third of the way back in the structure. You are inside the great ship, but the interior is flooded with sunlight through huge plate glass windows.

A steward guides you to your cabin. As to size and equipment, it is exactly

like a first-class steamship cabin for which you would pay \$250 on a good trans-Atlantic liner. Steamer trunks are stowed under the berths. The lavatory has hot and cold running water. Heat is furnished by electricity. A porthole looks out through the "view windows" to the ocean.

The bath, with showers, is just outside the cabin. You walk through the lounge. Passengers sit in club chairs, chatting, or at refreshment tables. You go down the



Drawing by
Carl W. Bertuch

central staircase to the dining saloon. Stewards are setting the tables for dinner. Accommodations are for fifty diners at a time. There are two long tables seating eight persons each; six that seat four each, and five that seat two. The electric range, with the busy chefs, is in one end of the saloon.

Now out on the promenade deck. It is thirty-six feet long and seventeen feet wide, on both sides of the passengers' saloon. A broad and strong walk, it extends from the sides of the cabins over to the huge "view windows." These are sections of clear plate glass rising outward at an angle of forty-five degrees. Easy chairs and tables are here for those who would sit and watch the panorama unfolding below. At night you will dance on this polished deck to radio music from New York and London.

HALF of the cabins are on this deck, half on the deck above. We go down the last flight of stairs to the crew's quarters. Here are the captain's cabin, the chart room, and the quarters of the three navigating officers, the coxswain, the elevator coxswains, the riggers, the fuel tender, the chef, and the stewards. Their dining room is just below.



An actual photograph of the saloon in the interior of the *R-100*. One would think the picture was taken in a hotel or some great ocean liner.

DANCING, Real Beds, and Hot and Cold Water Are Among the Luxuries of the Great Sky Liners Being Constructed for Trans-Atlantic Passenger Service. The Trip Will Cost the Traveler \$400 and the First Flight Is to Be Made in Early Fall

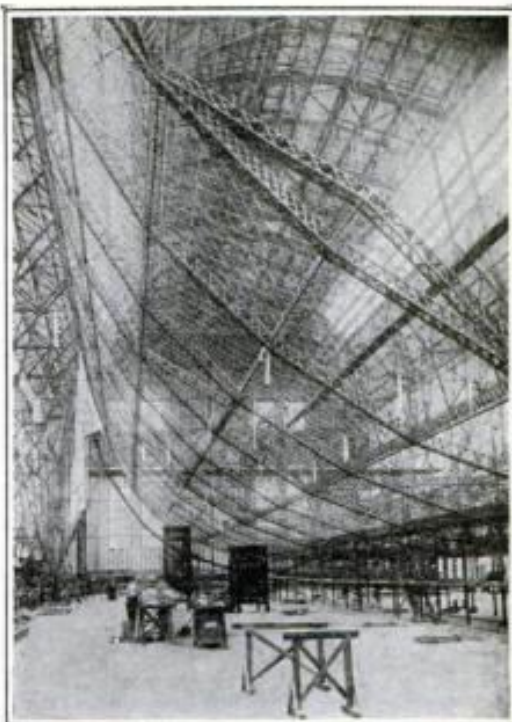
Down a ladder to the control car, where the helmsman is at the wheel and the captain-commander stands over his instruments. Immediately aft is the wireless cabin, with a radio operator on duty night and day.

Another gangway runs along just above the keel to the amidships and after engine cars, and to the freight rooms between them. But passengers are not permitted to wander that far. There is plenty to see up above, to be sure!

quarters, and two large ventilating shafts provide a constant circulation of fresh air.

The interior of the great hull resembles the skeleton of a modern steel skyscraper with its maze of beams and girders and braces. Whereas the earlier airships were made of duralumin girdering, the framework of the *R-100* is of duralumin tubing, ten miles of it, remarkably light and enormously strong.

The outer envelope is made of



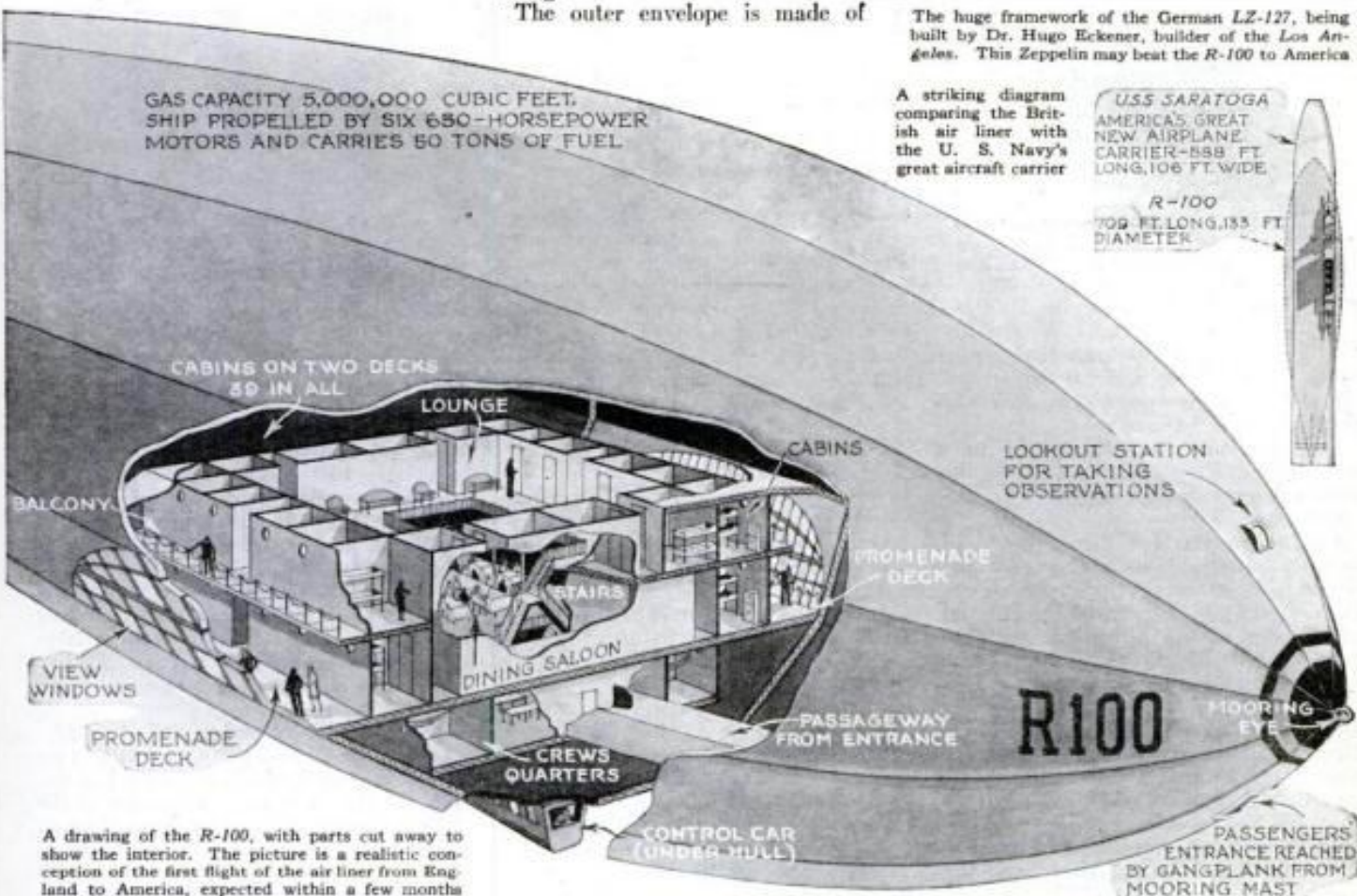
The huge framework of the German *LZ-127*, being built by Dr. Hugo Eckener, builder of the *Los Angeles*. This Zeppelin may beat the *R-100* to America.

GAS CAPACITY 5,000,000 CUBIC FEET.
SHIP PROPELLED BY SIX 650-HORSEPOWER
MOTORS AND CARRIES 50 TONS OF FUEL.

A striking diagram comparing the British air liner with the U. S. Navy's great aircraft carrier

USS SARATOGA
AMERICA'S GREAT
NEW AIRPLANE
CARRIER—888 FT.
LONG, 106 FT. WIDE

R-100
709 FT. LONG, 135 FT.
DIAMETER



A drawing of the *R-100*, with parts cut away to show the interior. The picture is a realistic conception of the first flight of the air liner from England to America, expected within a few months.

The structure housing these three decks is slung from the framework of the hull. It is fifty-three feet wide, thirty-six feet fore and aft, and twenty-seven feet high. The passengers' quarters are completely contained within the dirigible proper, and only the control car, set directly under the keel, and the three engine cars are exposed. The framework of the structure, reinforced with duralumin at points of greatest stress, is built of fireproofed balsa wood and fireproof fabric. A tight fabric ceiling keeps gas from escaping down into the passengers'

225,000 square feet of specially treated fabric. Up in the framework are the fifteen mammoth gas envelopes which give the ship a gas capacity of 5,000,000 cubic feet.

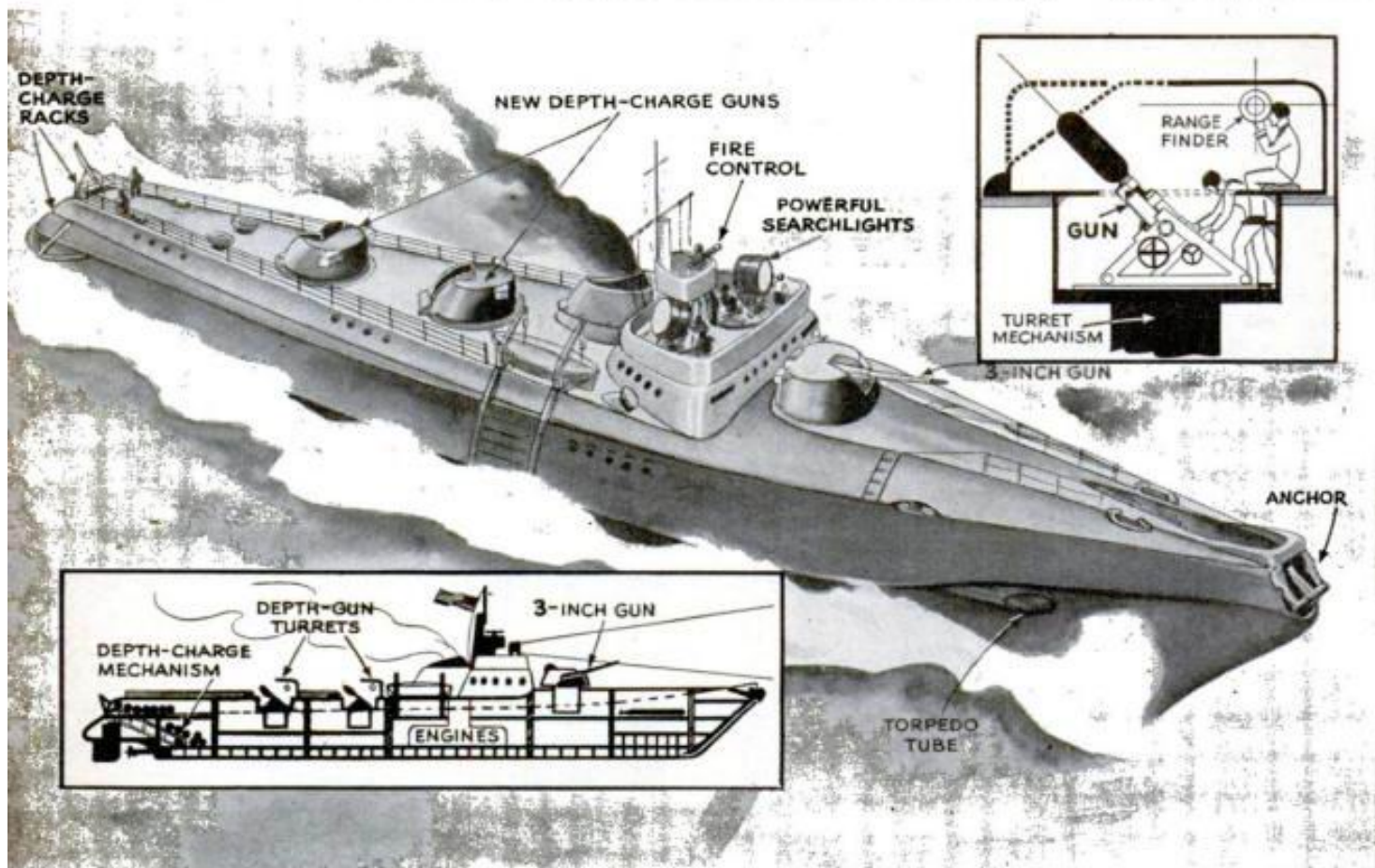
The six engines, each of 650-horsepower, are the Rolls-Royce Condor type. There are two in each of the three engine cars—two abreast on port and starboard of the lower frame, and the third further aft, slung below the center line. In these cars also are the smaller motors for lighting and heating the ship and for driving the dynamos.

Specially-made tanks in the rear of the ship hold fifty tons of fuel. At the stern are the upper and lower rudders, upper and lower fins, the two "elevators," and the elevator fins. In the bow, above the mooring eye, is a lookout station, reached by a ladder, from which the navigating officers take their observations.

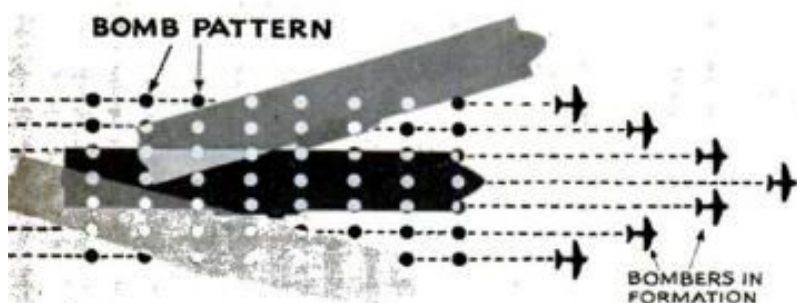
This is the good ship *R-100*, in truth a three-story "flying hotel," destined, unless all signs fail, to be the first across.

The makers of the German passenger dirigible, *LZ-127*, still hope to be first, but delays in *(Continued on page 122)*

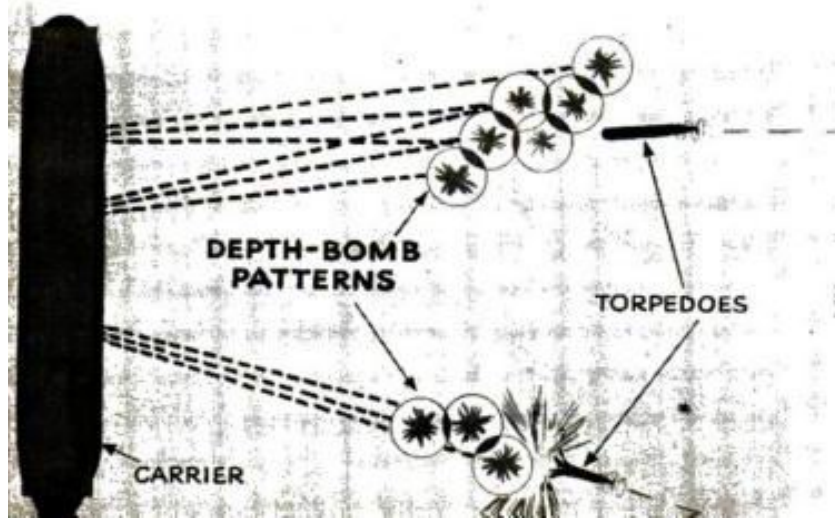
..... AND THESE SUGGESTIONS HOLD PROMISE



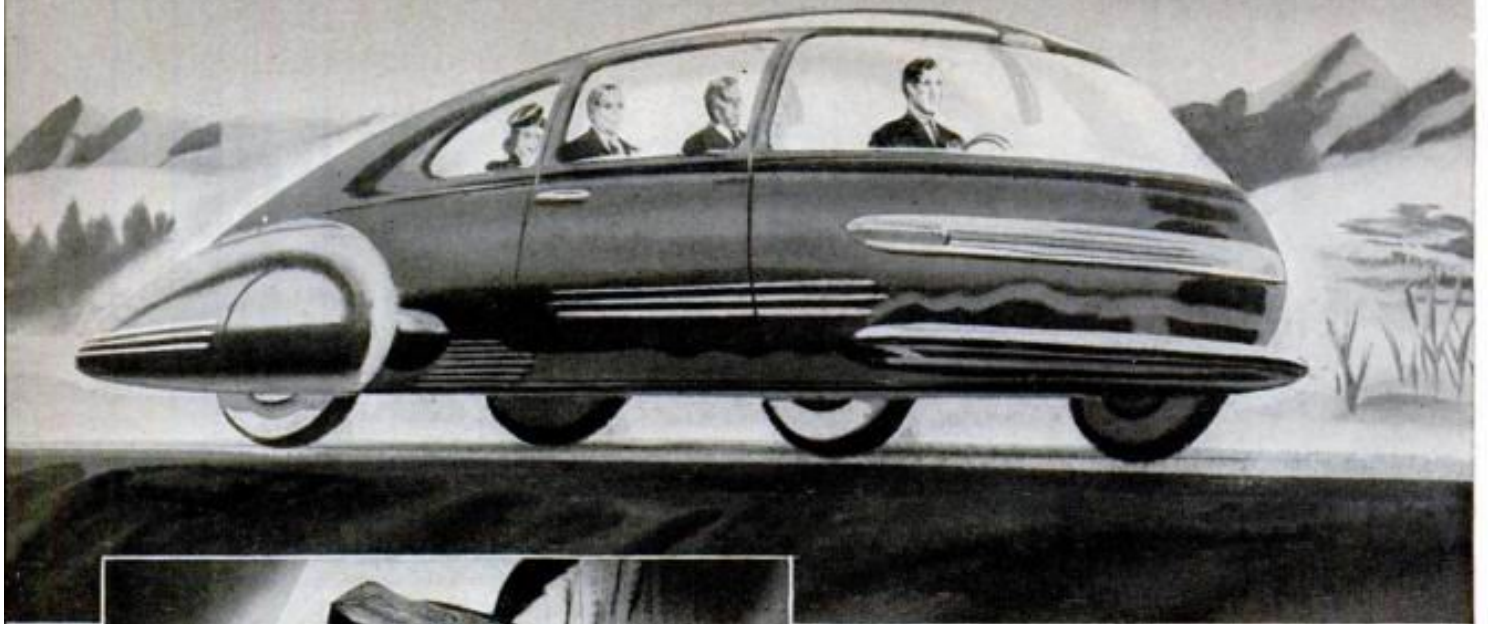
FAST SUB CHASERS like this, armed with long-range depth-charge guns, could make short work of U-boats. Unlike the familiar Y gun, these weapons would place charges accurately at great distances



DEFENDING A CARRIER. Horizontal bombers attacking a carrier must lay a bomb pattern like that shown above, and the best protection is an umbrella of fire from "flak ships." Against the equally deadly torpedo plane, Martial & Scull propose a screen of depth-charge explosions which would explode torpedoes or turn them aside from their course



BECAUSE it carries the longest-range artillery—namely, the bomber—the aircraft carrier has become about the most important of naval vessels, but it is also the most vulnerable. To protect it against its deadliest enemies, bombers and torpedo planes, is the purpose of two inventions of Martial & Scull, industrial designers of New York City. One is a "flak ship," a floating anti-aircraft battery designed as an escort vessel for carriers. Heavily armed with rapid-firing long-range guns, several of these could establish a rectangle of explosions at various levels above a carrier to break up bomber formations. The other invention is a gun for firing depth charges at long range to form a screen that would explode or deflect torpedoes dropped by planes. Guns of this type could also be mounted on fast sub chasers like the one shown in the artist's drawing at the top of this page.



Rayon-cord fabric is making Army tires stronger. After the war, long-wearing synthetic-rubber tires with rayon cord will be available to civilians

supplied by the major U. S. industrial concerns, research organizations, designers, engineers, and Government technical bureaus.

Right at the start it can be said with certainty that our life in the future will be characterized by greatly speeded-up transportation and the extensive use of new building and fabricating materials, both natural and synthetic.

No field has more dramatic possibilities than that of transportation, and the greatest developments, of course, will come in the air.

The war's end will find America with many thousands of bombing and air-transport planes, some of which will be almost immediately convertible to peacetime use.

In addition, we will have unrivaled facilities for building and designing planes, and it is certain that entirely new types must and will be developed to meet the keen international competition which is

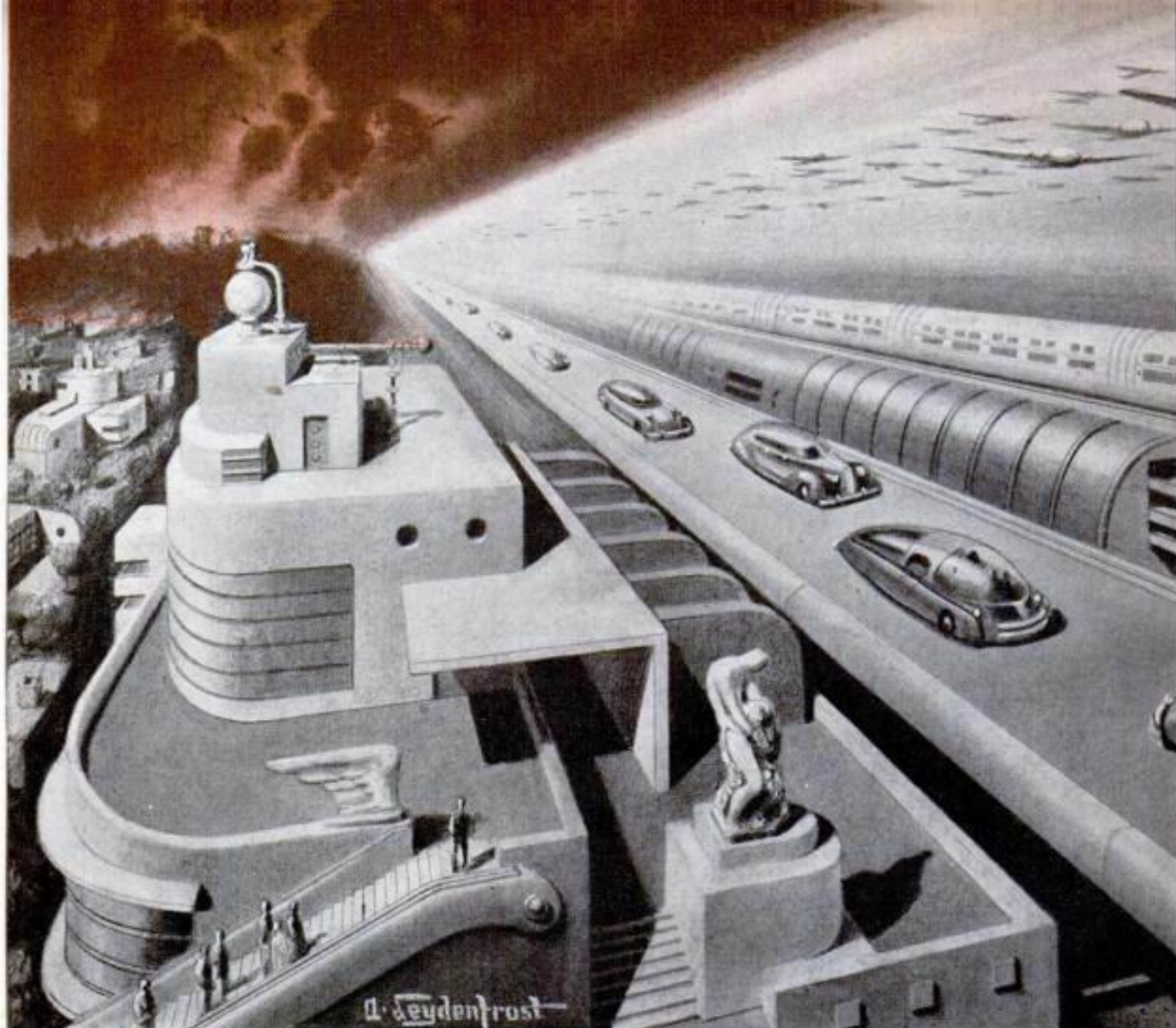
TOMORROW'S CAR. Automotive engineers looking ahead to postwar designs foresee lighter, cheaper, and safer cars. Plastic tops, frameless chassis, hydraulic drives, superchargers, lighter engines, and streamline bodies are slated for after the war. As for price—estimates range from \$500 to \$1,000 for small cars, and from \$1,200 to \$3,000 for larger models. As for economy—the smaller cars will give at least 30 miles to the gallon while even the larger cars will be expected to give 20 miles. Regular-grade gasoline will be 80 octane; premium grade, 100 octane

sure to spring up. We will have one other great advantage, already in being, in our elaborate Army Air Transport Service, with all the major U. S.

air lines co-operating in maintaining service all over the world on a scale of organization scarcely dreamed of three years ago.

The cargo plane of the future will be specially designed for its work, will have a very high lift factor, will have both nose and side hatches for loading cargo, and will have a relatively low landing speed to get into small airfields.

If airmen are inclined to speculate mostly on their future cargo business it is not because they aren't interested in passenger traffic, but rather because they take it pretty much for granted that planes will be the normal medium of high-speed travel over any reasonably long distances. Giant passenger planes are sure to come along; there can't be a designer in the business who hasn't at least sketched out an idea for a super-airliner complete with sun lounge, promenade deck, eight engines, etc., and some of these designs had been well publicized even before the war. Most



War's End *will*

By JOHN H. WALKER

AFTER this war is won, the American people should be able to travel faster and live better than ever before. The money and energy being poured into our war effort now will pay us dividends years after the victory itself.

Three main factors in the war effort guarantee a better life for Americans:

New Plant.

New Discoveries.

New Skills.

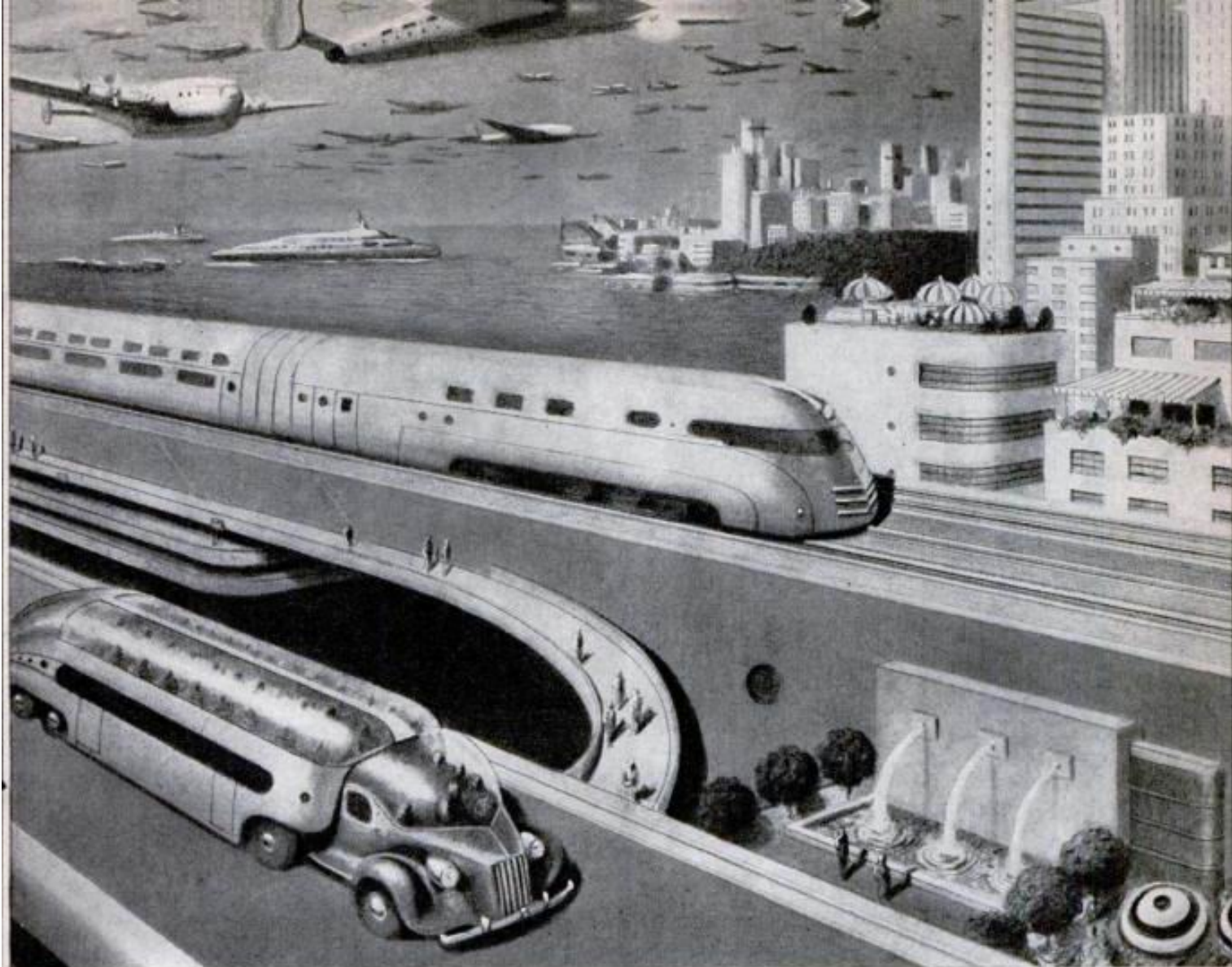
War secrecy bars any complete compilation of the tremendous plant expansion carried on in the past two years. Some of the new factories and arsenals have been well publicized, while others have been discreetly played down to avoid attracting the attention of saboteurs or revealing too much about our

war-material manufacturing schedules. But that expansion has been on a huge scale. One good example which can be cited is that of the shipbuilding industry, which has expanded to something like 600 percent of its former capacity.

We have entire new factories in the Middle West, built to produce tanks, bombing planes, and engines. And very much in the public eye are the new oil pipe lines being built to supplement our existing system linking oil fields to industrial areas.

All this new plant is destined to become a permanent part of our industrial heritage. The problem of reconversion to civilian use may be a knotty one in some specialized cases, yet the fact remains that we will have this new equipment to use.

New discoveries most certainly will flow into the current of our economic life under



bring a better life

the pressure of greatly increased wartime research by almost every branch of industry. Chemistry, metals, plastics and glass, electricity and radio, construction, communication and transportation, fabrics and food and medical science—all these and virtually every other field of human activity will experience the forward thrust of research and development carried out under forced draft.

Along with this forced advance of technology will go a wartime pooling of brains and patents in industry, and it is not too much to say that before the war is over millions of Americans, young and old, will have learned some kind of new skills, making them better fitted to work and produce for the greater wealth of the whole nation.

New skills not only make new industries possible; they make them inevitable. Take

one example: Hundreds of thousands of young Americans will have learned how to fly or navigate or overhaul airplanes in this war. Afterward they will want light planes to fly, even if they return to totally different civilian work. That demand will create a private-airplane industry far beyond anything we have known. Many aeronautical scientists believe that the plane these people will really want is a workable helicopter type, able to land and take off almost vertically, at dead slow speed. And that, in turn, is a problem for research; there will be no lack of plant to build the ships.

We can't look far enough into the mist of the future to assemble any detailed list of things to come. Yet the broad general outlines of a better life are clearly distinguishable. Our interpretation of these outlines has been based almost entirely on material

M-4 MEDIUM TANK
WITH 76-MM. GUN

M-31 TANK RETRIEVER
WITH 81-MM. MORTAR

M-36 MOTOR CARRIAGE
WITH 90-MM. GUN

M-18 MOTOR CARRIAGE
WITH 76-MM. ("HOLE PUNCHER") GUN

M-24 LIGHT TANK
WITH 75-MM. GUN

Drawing by
B. G. SEIELSTAD

Secrets of Our New Armor

HERE ARE SOME OF THE FAST, HARD-HITTING
COMBAT VEHICLES THAT BEAT THE PANZERS

HOW have American tanks and tank destroyers been able to outblitz German armor at its own game? Correspondents recently learned the answer when the Army exhibited some of its latest combat vehicles, and revealed hitherto secret facts about them, at its Aberdeen, Md., Proving Ground.

Light U. S. tanks now pack the punch of former "mediums," and our General Sherman M-4 medium tanks have slugged it out on even terms with monster German "heavies" like the Tiger and Panther. Bigger guns are one of the reasons. Largest weapon ever carried by a medium tank is said to be a 105-mm. howitzer mounted on some of our M-4's. High muzzle velocity, and armor-piercing shells, account for the destructiveness of the 76-mm. "hole puncher" gun of

other M-4 tanks, and of the self-propelled "motor gun carriage" or antitank weapon M-18. Its big brother, the 90-mm.-gunned M-36, is called the world's fastest major-caliber tank destroyer. It pursues and knocks out heavy enemy tanks at 30 miles an hour. High speed characterizes the Army's whole stable of combat vehicles, and its tactics in their use. A novelty in American light tanks, the airborne 37-mm.-gunned "Locust," lands from a glider and races along roads at 40 miles an hour.

Among special-purpose vehicles, tank-recovery cars dash onto battlefields to haul out disabled tanks, either by towing them or by taking them bodily aboard. From the high-speed armored utility car M-20, field commanders direct advancing motorized forces.



M-4 MEDIUM TANK
WITH 105-MM. HOWITZER



M-5 LIGHT TANK
WITH 37-MM. GUN

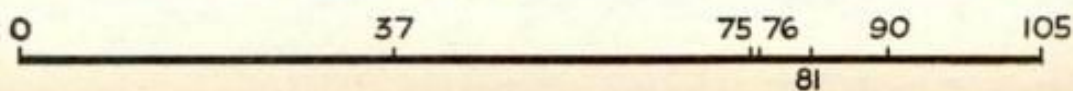
"LOCUST" AIRBORNE TANK
WITH 37-MM. GUN
(GLIDER IN BACKGROUND)

M-8 ARMORED CAR
WITH 37-MM. GUN

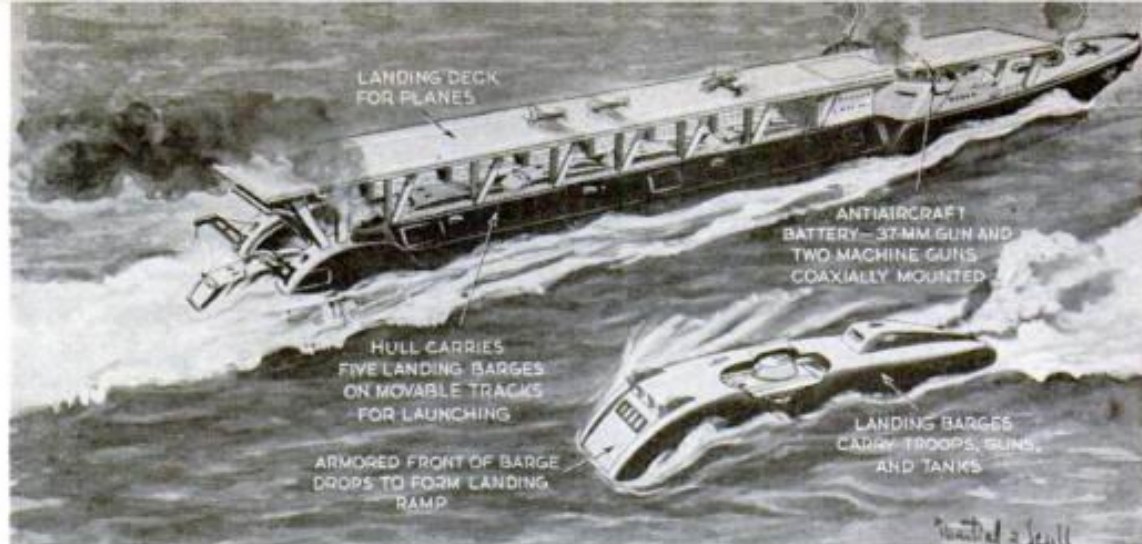
M-20 ARMORED UTILITY CAR
WITH .50-CAL. MACHINE GUN

**AMPHIBIOUS
WEASEL**

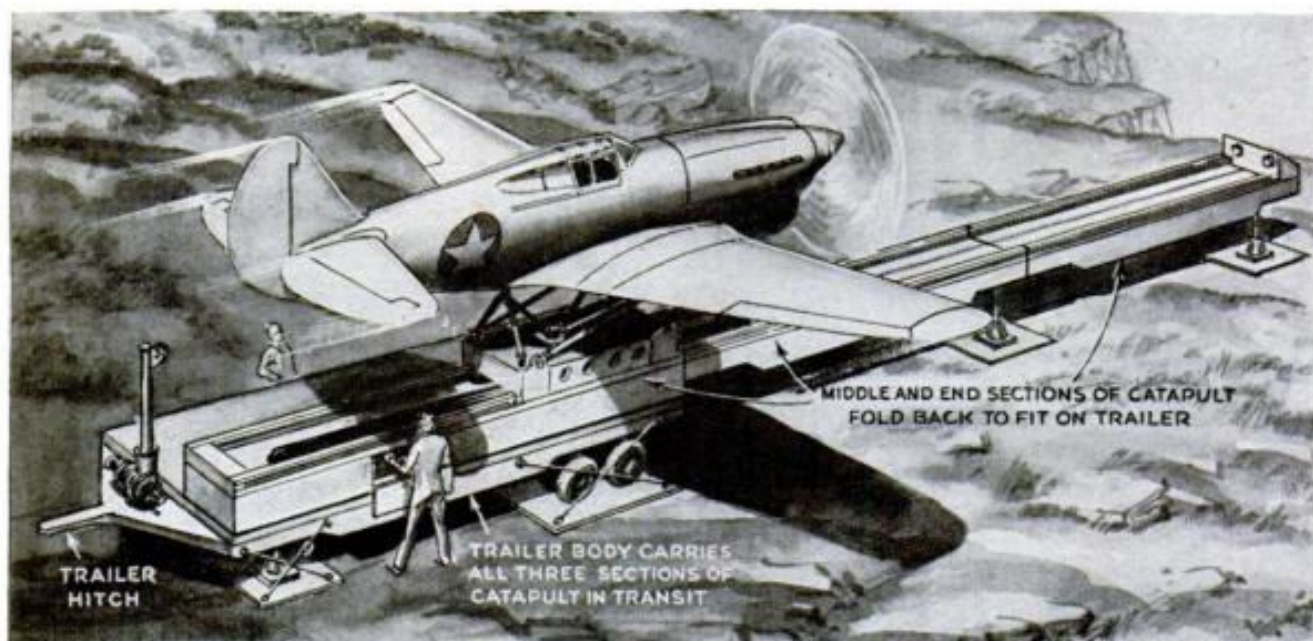
ACTUAL SIZES OF GUN CALIBERS IN MM.



WAR IDEAS

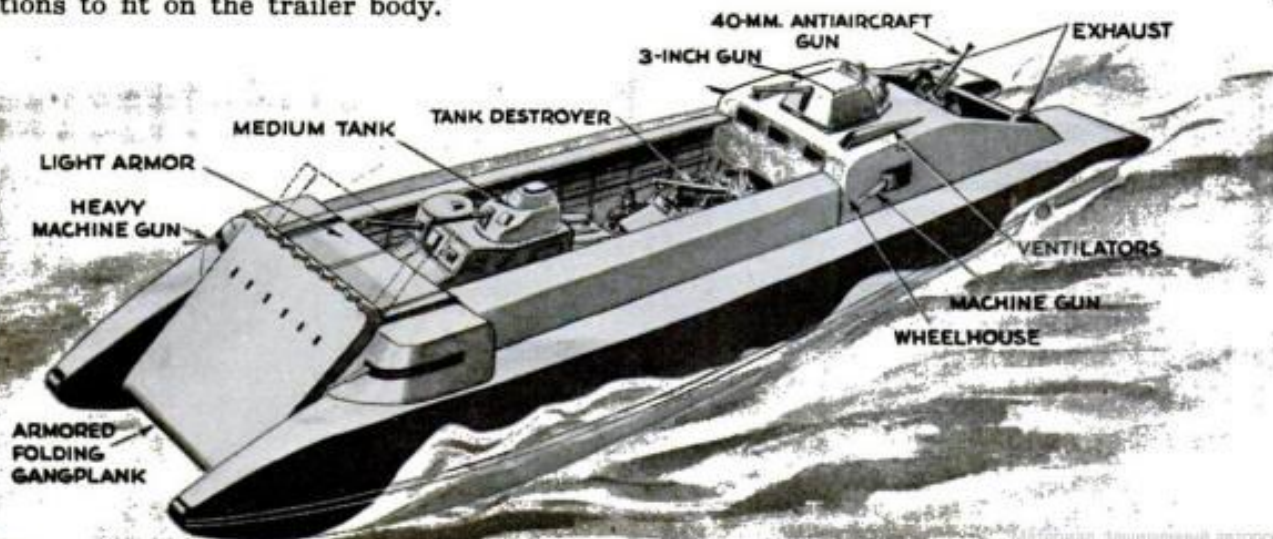


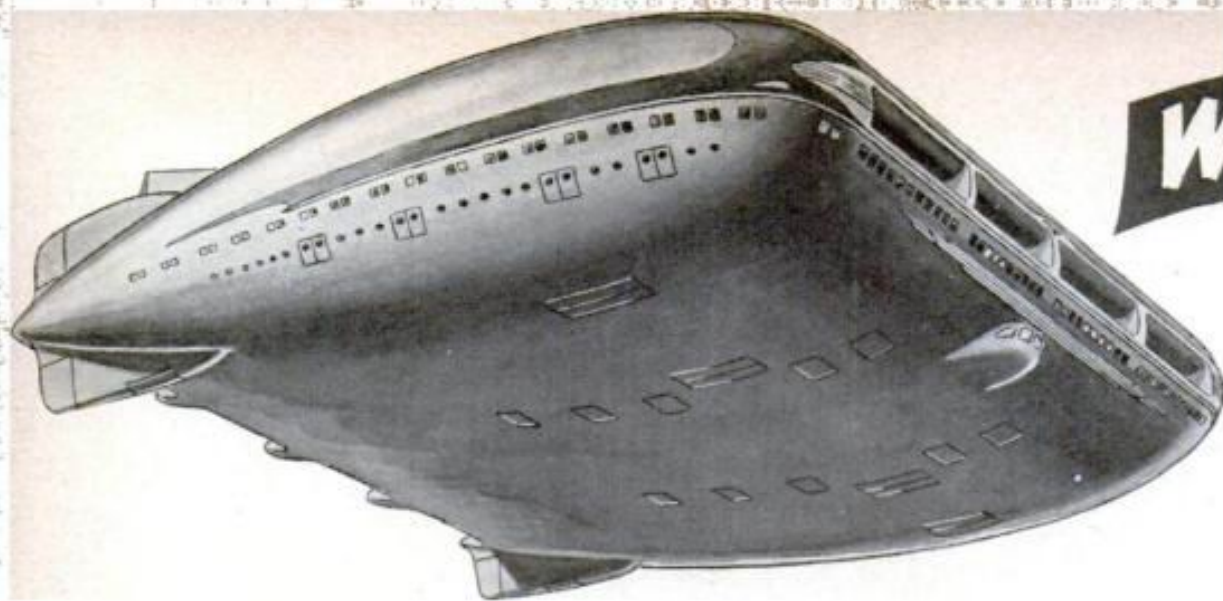
BARGE AND AIRCRAFT CARRIER, this invasion ship, conceived by Jacques Martial and Robert C. Skull, industrial designers, has combination smashing power. Its deck holds 15 to 20 bombers and protecting fighters. Under the deck are tracks for five barges, and retrieving cranes. The ship mounts three triple 37-mm. anti-aircraft guns, and can carry torpedo boats instead of barges.



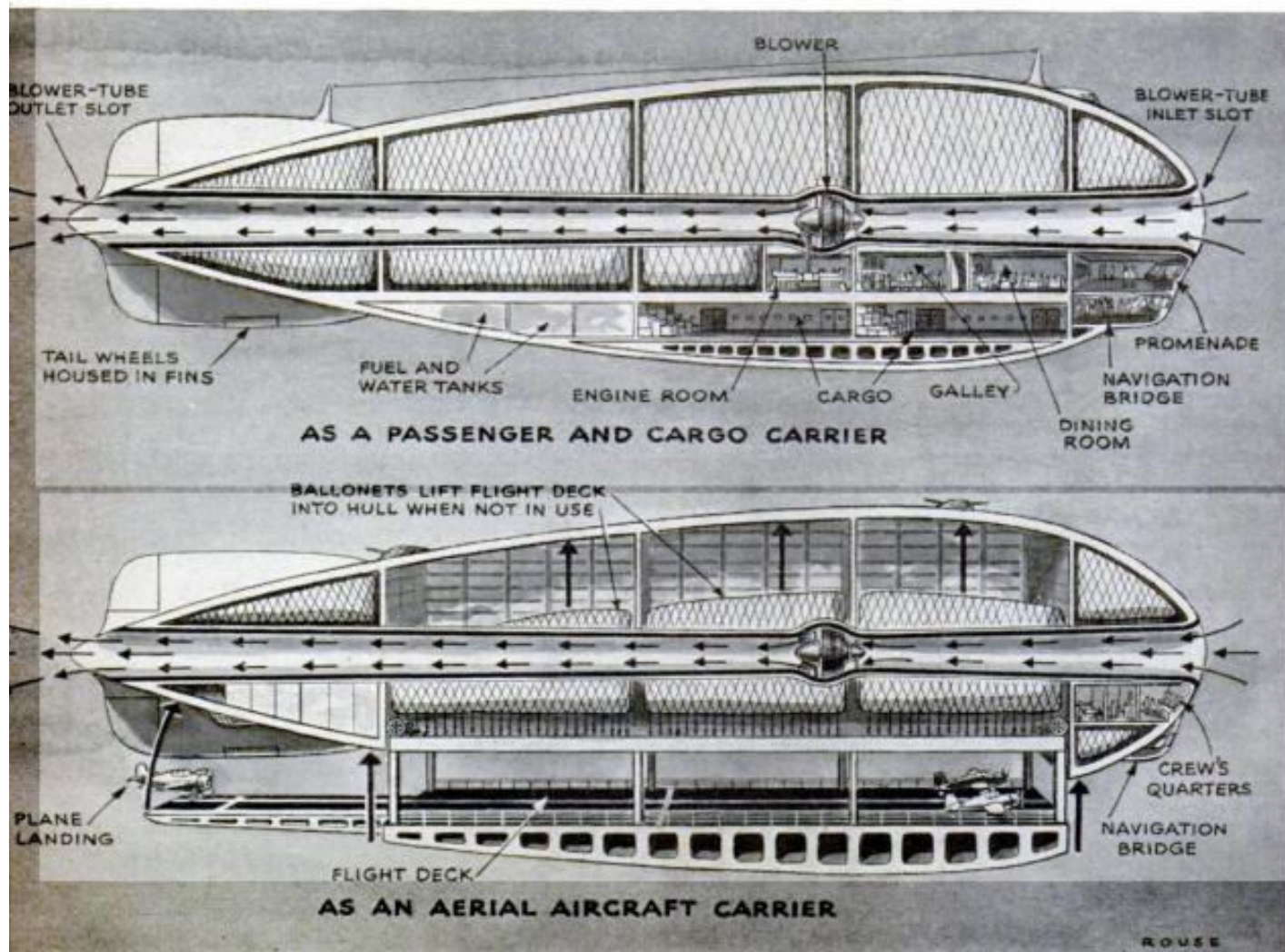
TRAILER PLANE CATAPULTS, such as the invention depicted above, may be hauled into place by truck, and fighting planes launched by them from front-line positions where it would be impracticable to clear out even temporary flying fields. The runway consists of a jointed track which folds in three sections to fit on the trailer body.

LANDING BARGE. This open-top landing barge, capable of carrying a medium tank and a self-propelled 75-mm. gun, is heavily armed. Besides four heavy machine guns and an anti-aircraft gun aft, it also mounts a 3-in. gun in a movable turret. The design is offered by Martial and Skull.





WAR

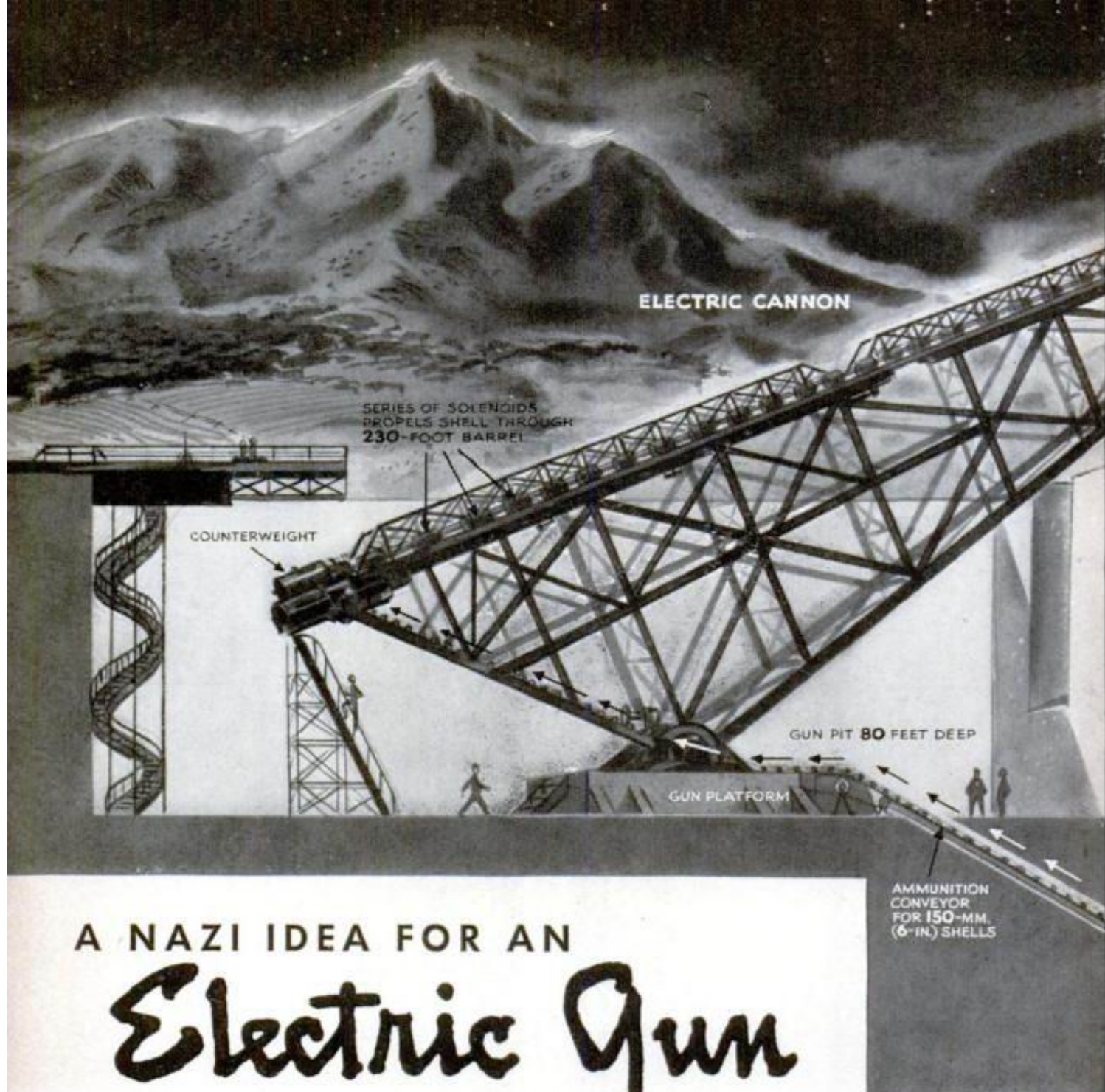


FLYING AIRCRAFT CARRIERS and huge troop and cargo air transports with a range of 8,000 miles have been designed by Horace Chapman Young and Eric Langlands as combinations of airship and airplane. The Airwing, as the craft is called, is built as a flying wing with space within its single-wing body for helium, fuel, crew, and pay load and tunnels in which propellers or blowers operate.

This wind-tunnel operation is based on the principle that the plane will both pull and push itself forward—pulling through suction caused by a semivacuum created in front, and driving by exhaust pressure at the rear.

The helium gives it additional lifting power, making a total load of 63 tons possible for a ship 250 feet square and 62½ feet in height. A troop transport of the same size would accommodate 300 soldiers fully equipped for service abroad. The aircraft carrier is designed with a flight deck 180 feet wide by 200 feet long that could be lowered below the hull to allow 12 fighter planes to take off and land.

Maximum speed is estimated at 240 miles an hour, take-off speed at 30, and landing speed at 20. The Airwing could cruise 270 hours at 30 miles an hour.



A NAZI IDEA FOR AN

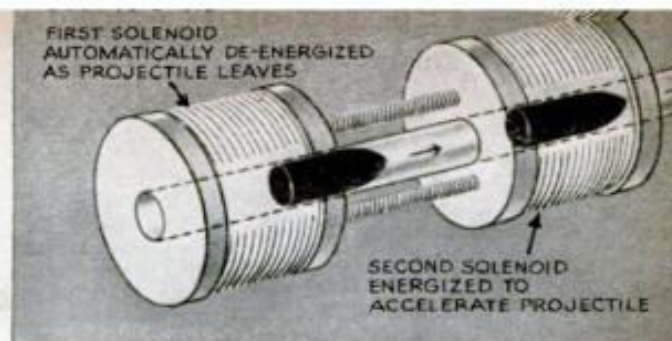
Electric Gun

IMAGINE a rapid-firing electric cannon, capable of raining 750 six-inch shells a minute upon a target 90 miles away! Out-ranging the long-distance guns that bombarded Paris in the First World War, such a weapon is proposed in a French edition of the German periodical "Signal." Is artillery of this kind to be a possibility of the future?

As depicted, the scheme calls for a huge gun with a thin 230-foot barrel. Solenoids, or coreless electromagnets, encircle the tube at regular intervals from its breech to its muzzle. When a firing switch is closed, the first solenoid magnetically attracts the missile and starts it on its way. As the shell passes through it, this solenoid goes dead

and the next one takes up the pull, until successive impulses give the projectile a muzzle velocity of more than a mile a second. A high-speed automatic conveyor feeds ammunition. When not firing, the gun lowers for concealment beneath camouflaged covers.

Formidable as it sounds, the idea invites critical analysis. First, just what is this gun intended to do? At its extreme range, precision firing upon small targets such as ships and troop concentrations would be out of the question. A more likely task would be to shell a large city at random. London could be bombarded from clear across the Channel. But here the gun takes on a job for which bombing planes are pre-eminently suited. Presumably the cannon would be of



MAGNETISM REPLACES POWDER IN THIS NAZI DREAM WEAPON

Looking more like a drawbridge than a piece of artillery, the odd structure at the left is our artist's conception of the electromagnetic cannon proposed in a German publication, as it rises from concealment to hurl 750 six-inch shells a minute at a target 90 miles away. Subterranean, bomb-proof galleries house the control room and ammunition magazine, from which an endless conveyor feeds shells automatically to the gun. Spaced along the slender tube as seen above, coreless electromagnets are energized in rapid succession to whip the projectiles through the barrel, which they leave with a muzzle velocity of more than a mile a second. Absence of



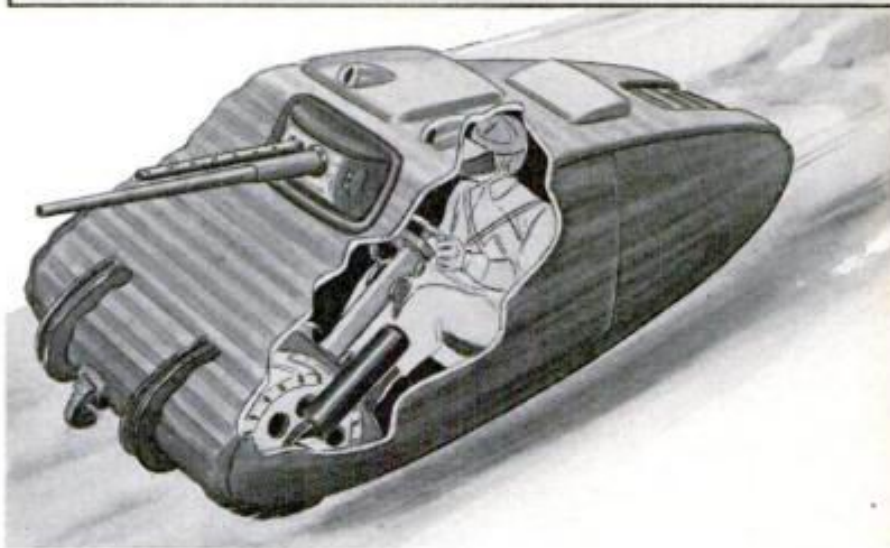
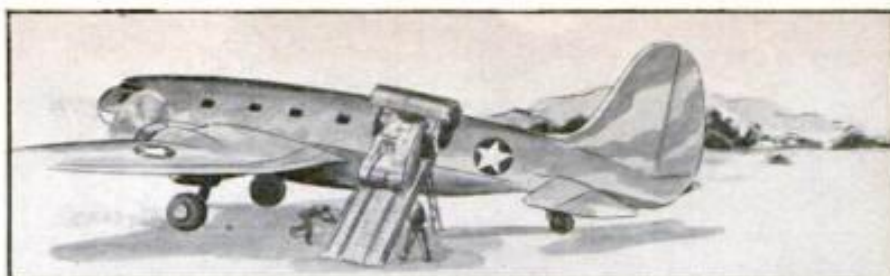
most interest to a belligerent shorn of air power. The damage inflicted by one of its high-explosive shells would be exceeded by an air bomb of only 250 pounds—a modest size, indeed, compared to a modern 4,000-pound "block buster."

An embarrassing problem remains—where to get the 1,000,000 kilowatts of power needed to operate the gun. No generating station in all of Germany has this capacity. Interconnected sources of current might be used, but only at the cost of a "blackout" of vital Axis industries using electric power. Perhaps the grandiose idea simply needs radical scaling down. Small electric guns have been devised by inventors in many lands, and some model may yet compete with those that use gunpowder.

explosive blast makes a thick barrel unnecessary, and recoil takes effect only on the magnets and their supporting framework. Shells of special design could be rotated electrically to steady their flight, the effect obtained by rifling in an ordinary cannon. A vulnerable target for hostile bombers because of its fragile construction, the gun may be shifted from one emplacement to another in three sections, on trailers drawn by powerful towing trucks. The sketch above shows the 230-foot tube being reassembled at an emplacement. For comparison, a conventional gun of the same caliber has a 20-foot barrel and a maximum range of about 14 miles

TWO-MAN PARATANKS

small enough to be transported in cargo planes are proposed by Martial and Scull, industrial designers, to provide a quick means of landing mechanized equipment behind enemy lines. The all-welded tank at right is triangular in shape with two forward wheels and a track-type runner in the rear. It carries a 37 - millimeter antitank gun coupled with a heavy machine gun. The occupants also have submachine guns and grenades.



EXTRA FOLDING WINGS on a plane proposed by Byron T. Wall, of Raymond, Alta., Canada, increase the wing area and drag, allowing it to take off and land at the low speed of a biplane and yet retain the longer flight range and high speed of a monoplane when it is in the air. The auxiliary wings are raised before the take-off, giving the plane extra lift and requiring a much shorter run—an important consideration on small fields.

When sufficient speed has been attained in the air, the auxiliary wings are retracted, folding into the fuselage and lower wings and eliminating the drag of struts and extra wing area. Recesses in the fuselage and lower wings cut resistance when the upper wings are folded. In landing, the procedure is reversed, with the upper wings being separated from the lower at an angle beginning at the outer edges. This offsets suction that would tend to hold the wings together if the action were in parallel planes.

1 FOR HIGH SPEED

SMALL WING AREA GIVES HIGH SPEED, BUT SAFE LANDINGS ARE IMPOSSIBLE



CONTRA-ROTATING PROPELLERS

2 TRANSITION FROM SMALL TO LARGE WING AREA

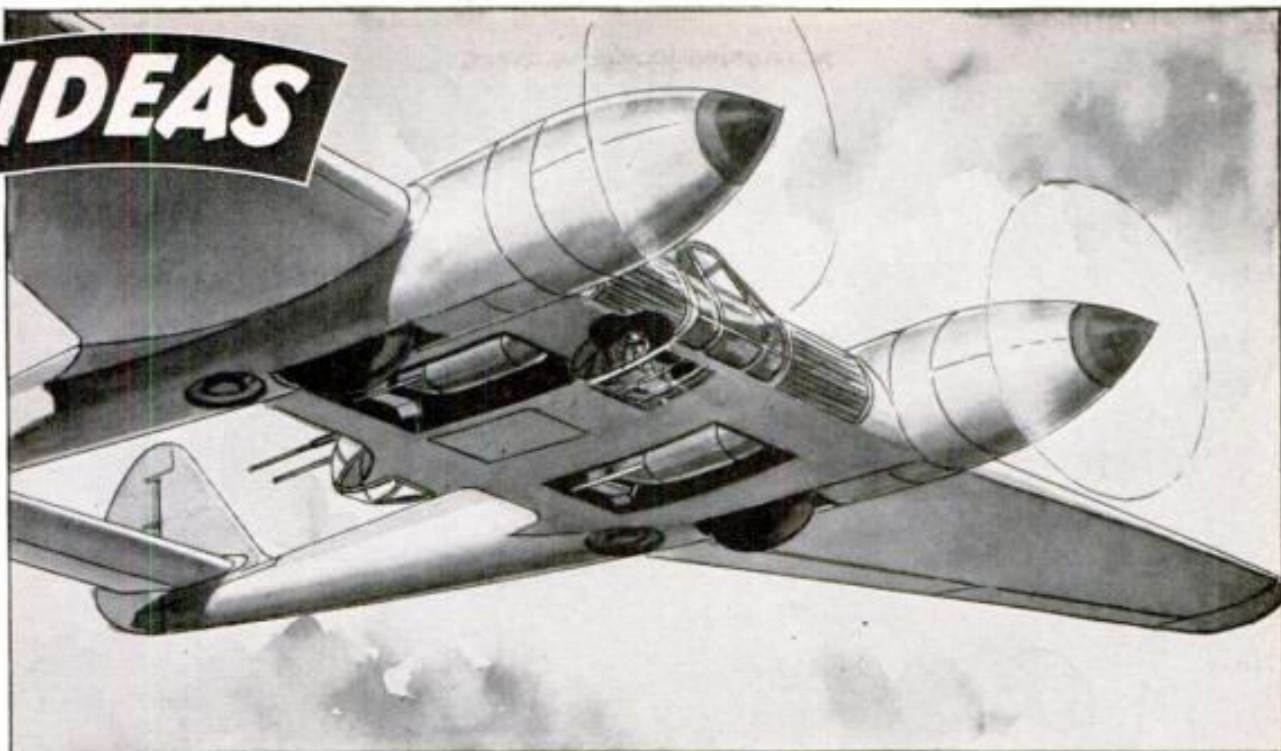
UPPER WING UNFOLDS TO CONVERT MONOPLANE INTO A BIPLANE

3 FOR LOW-SPEED FLIGHT AND SAFE LANDINGS

AS A BIPLANE, THE PLANE'S WING AREA IS DOUBLED

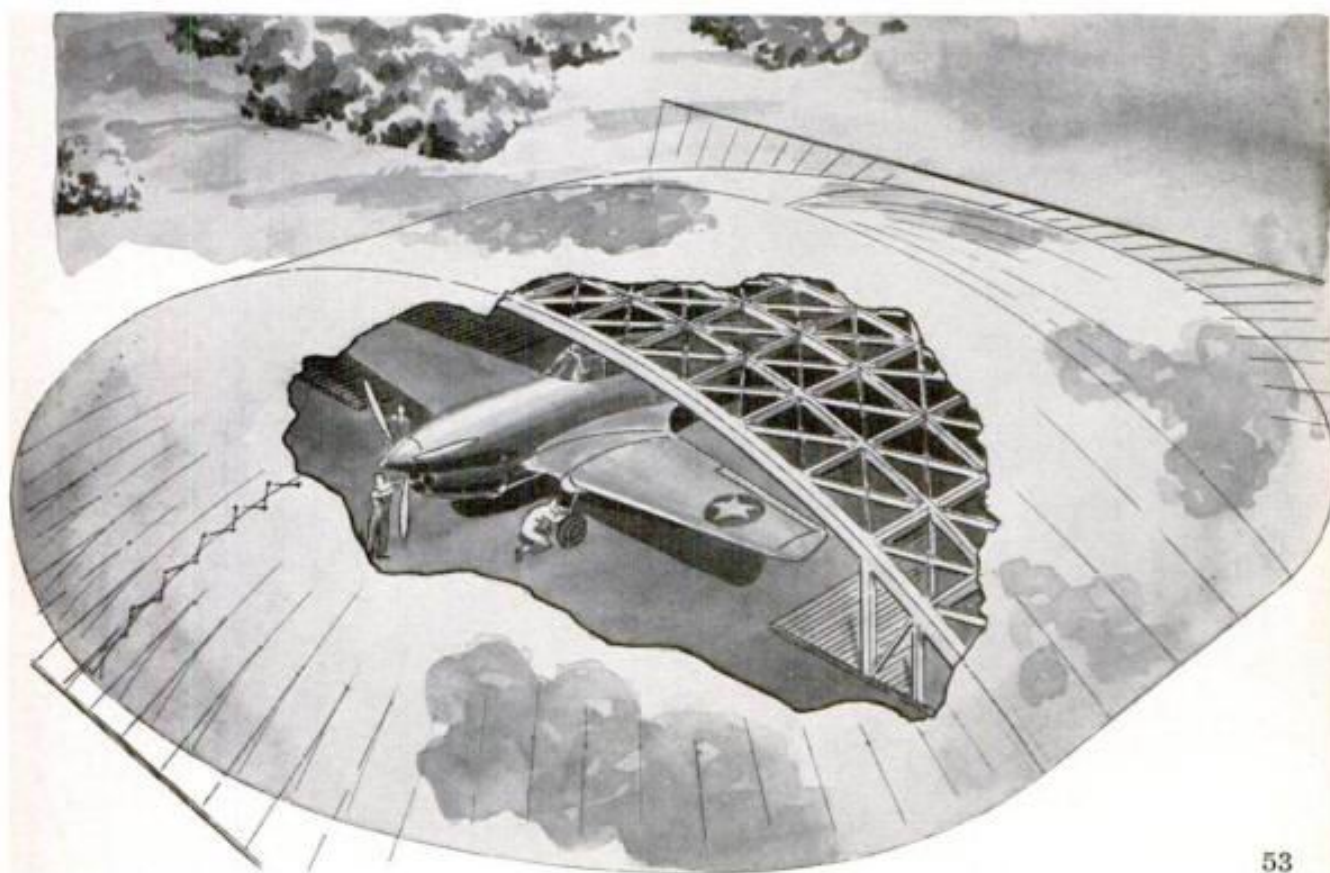


IDEAS



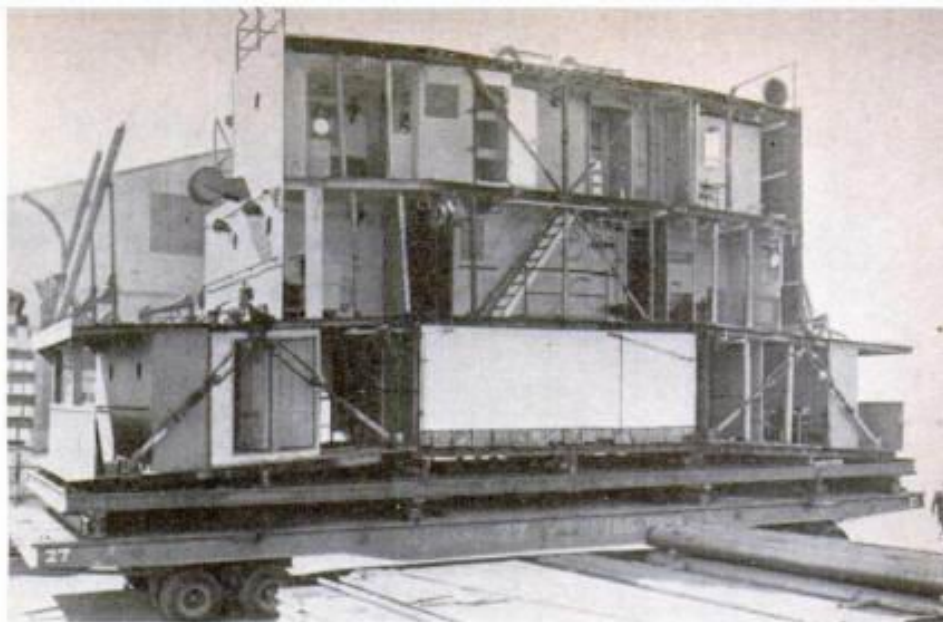
TWO BOMB COMPARTMENTS are provided in a newly designed all-wing plane with quarters for pilot and crew in the central wing section, which is of airfoil contour and contributes to lift as well as housing the load. This central portion has a maximum height of $5\frac{1}{2}$ feet which is reduced to $3\frac{1}{2}$ feet on either side of that part used by the crew. In addition to its bombing devices, the plane carries both forward and rear guns—the latter being capable of full vertical range.

QUICKLY SET UP SINGLE-PLANE HANGARS, easily camouflaged with their turtle-back design eliminating shadows, have been patented here and in England. The arched-rib framework—steel for large hangars or trussed wood for small ones—is roomy enough to accommodate personnel. Its canvas covering can be drawn back for openings at both ends. By use of roofs and partitions, the shelters could easily be adapted to temporary housing for another purpose.

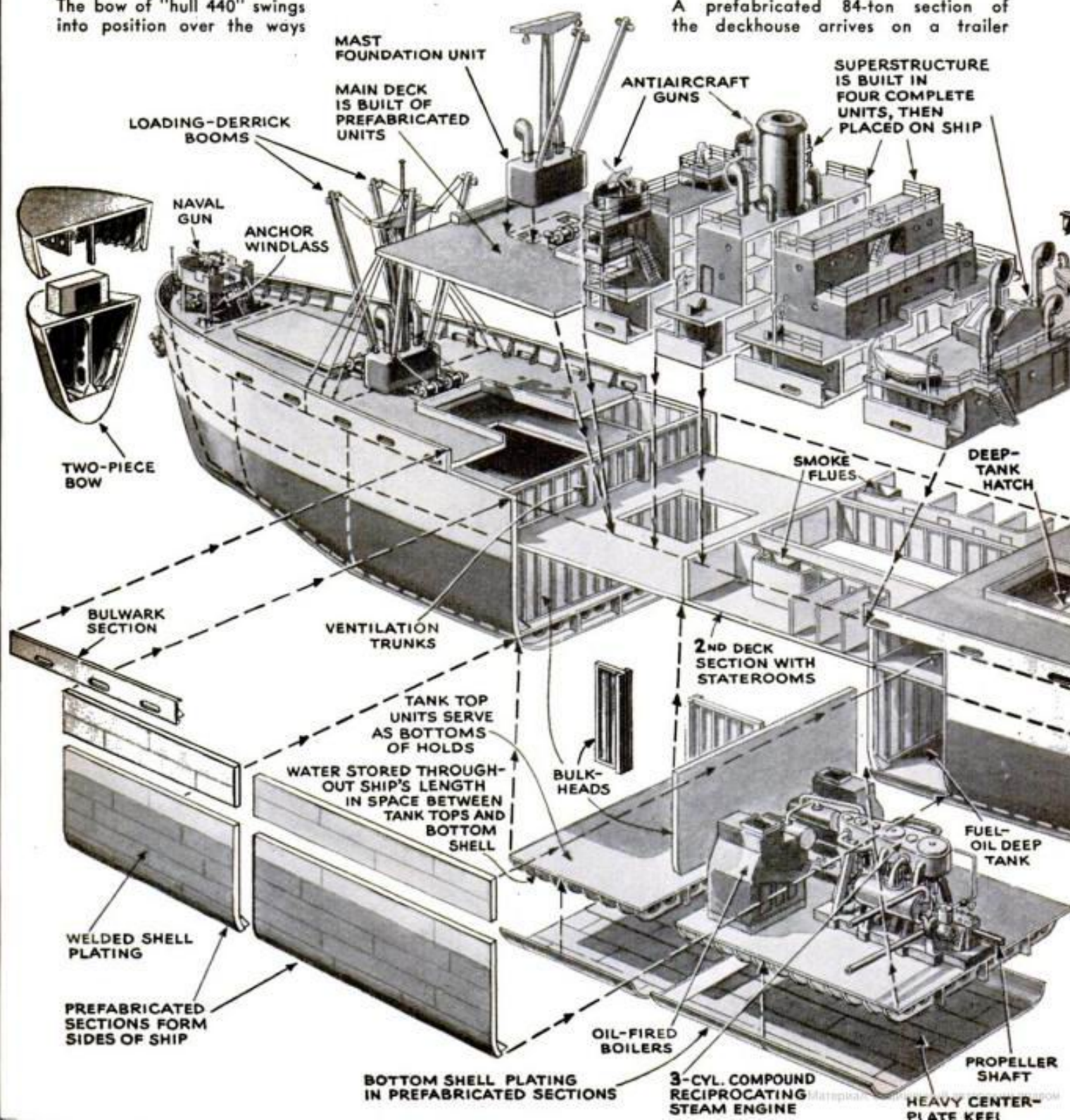




The bow of "hull 440" swings into position over the ways



A prefabricated 84-ton section of the deckhouse arrives on a trailer

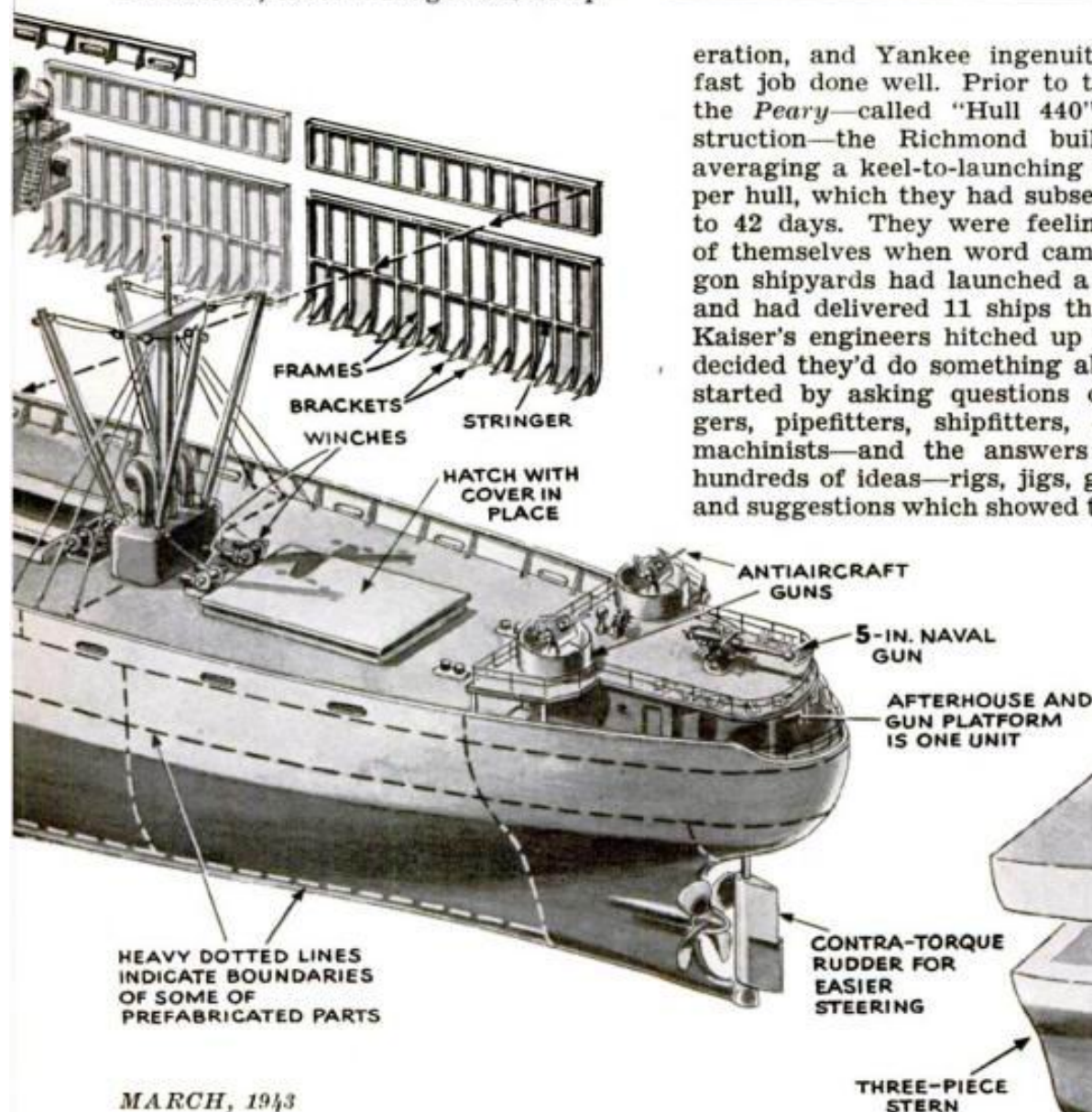
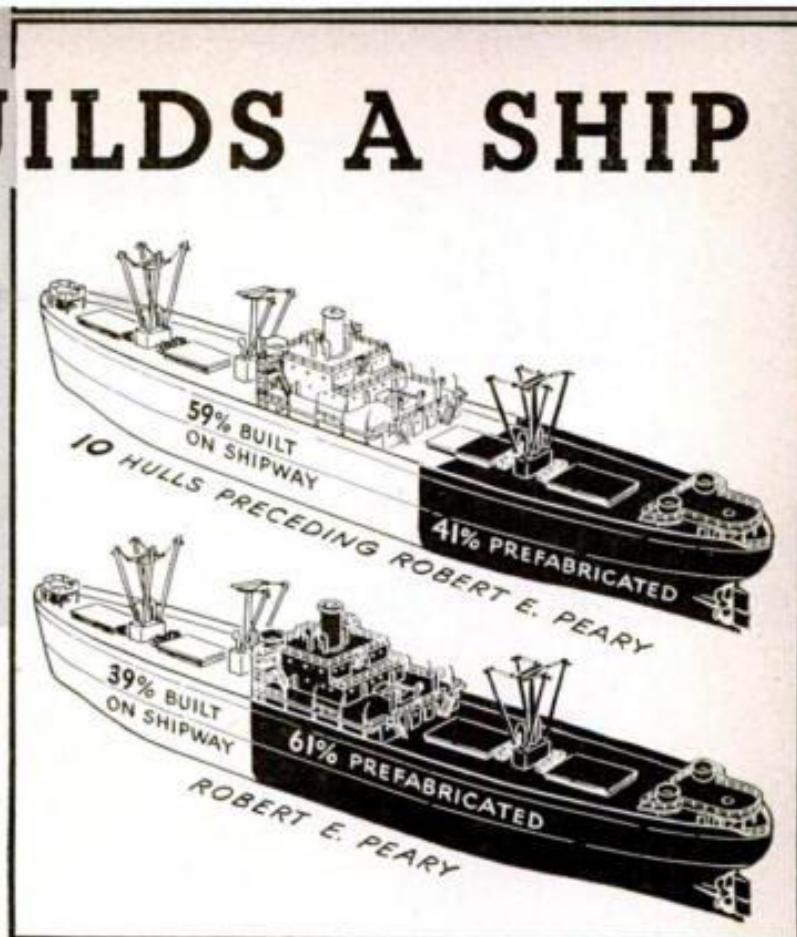


WHAT HAPPENS WHEN KAISER BUILDS A SHIP

A JIGSAW PUZZLE OF STEEL,
WITH A QUARTER OF A
MILLION PIECES AND 97 PRE-
FABRICATED SECTIONS, FORMS
A NEW VESSEL FOR VICTORY

DRAWINGS BY STEWART ROUSE

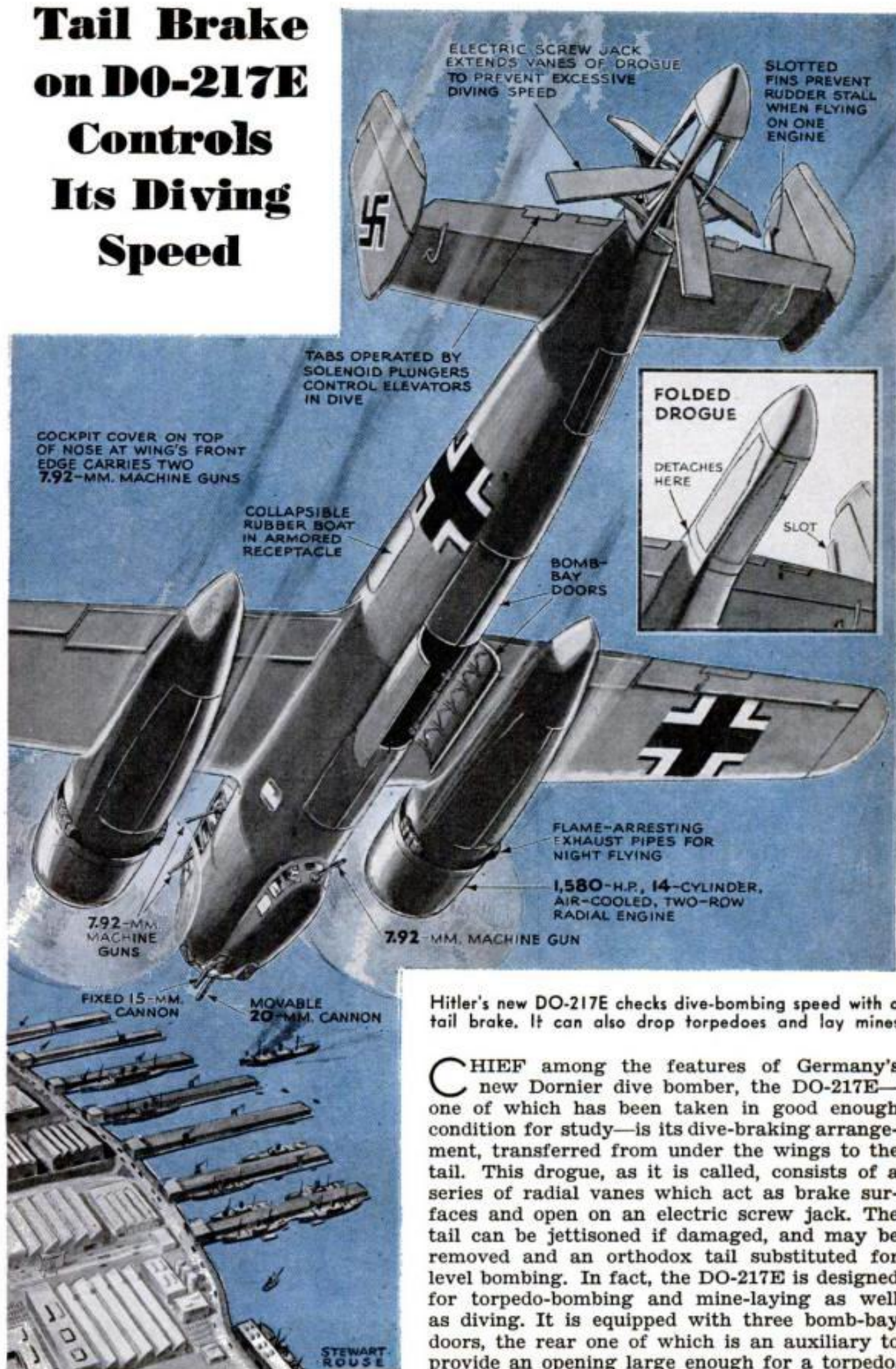
WHEN the 10,500-ton *Robert E. Peary*, on November 12, 1942, slid down way No. 1 of Henry J. Kaiser's Richmond shipyard after being on the ways only four days, 15 hours, and 26 minutes, it did more than set a world's record in speedy shipbuilding. It set records in prefabrication, labor-management co-op-



eration, and Yankee ingenuity in getting a fast job done well. Prior to the launching of the *Peary*—called "Hull 440" while in construction—the Richmond builders had been averaging a keel-to-launching time of 57 days per hull, which they had subsequently lowered to 42 days. They were feeling pretty proud of themselves when word came that the Oregon shipyards had launched a hull in 10 days and had delivered 11 ships that same month. Kaiser's engineers hitched up their pants and decided they'd do something about that. They started by asking questions of welders, riggers, pipefitters, shipfitters, draftsmen, and machinists—and the answers came back in hundreds of ideas—rigs, jigs, gadgets, devices, and suggestions which showed that the workers

MARCH, 1943

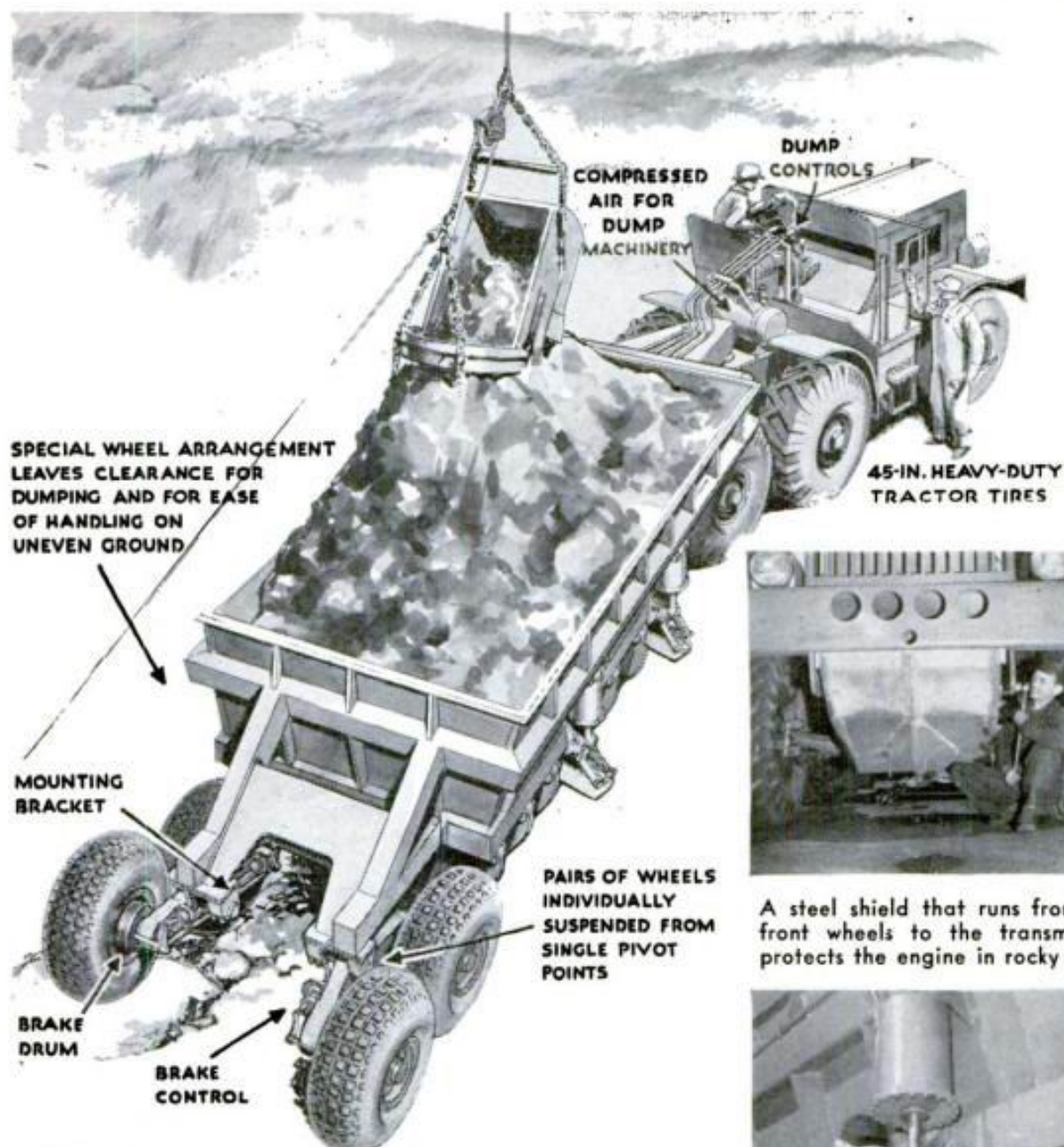
Tail Brake on DO-217E Controls Its Diving Speed



Hitler's new DO-217E checks dive-bombing speed with a tail brake. It can also drop torpedoes and lay mines

CHIEF among the features of Germany's new Dornier dive bomber, the DO-217E—one of which has been taken in good enough condition for study—is its dive-braking arrangement, transferred from under the wings to the tail. This drogue, as it is called, consists of a series of radial vanes which act as brake surfaces and open on an electric screw jack. The tail can be jettisoned if damaged, and may be removed and an orthodox tail substituted for level bombing. In fact, the DO-217E is designed for torpedo-bombing and mine-laying as well as diving. It is equipped with three bomb-bay doors, the rear one of which is an auxiliary to provide an opening large enough for a torpedo.

Trailer Truck Moves Muck in 80-Ton Loads

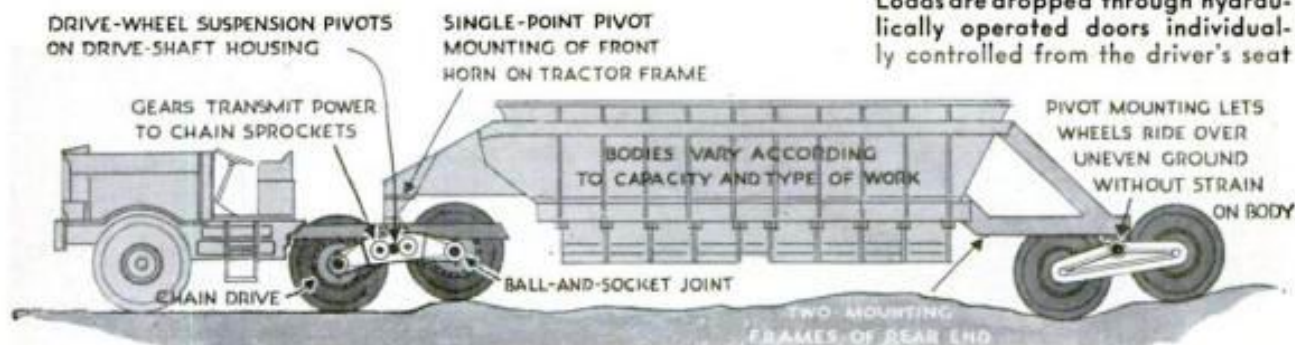


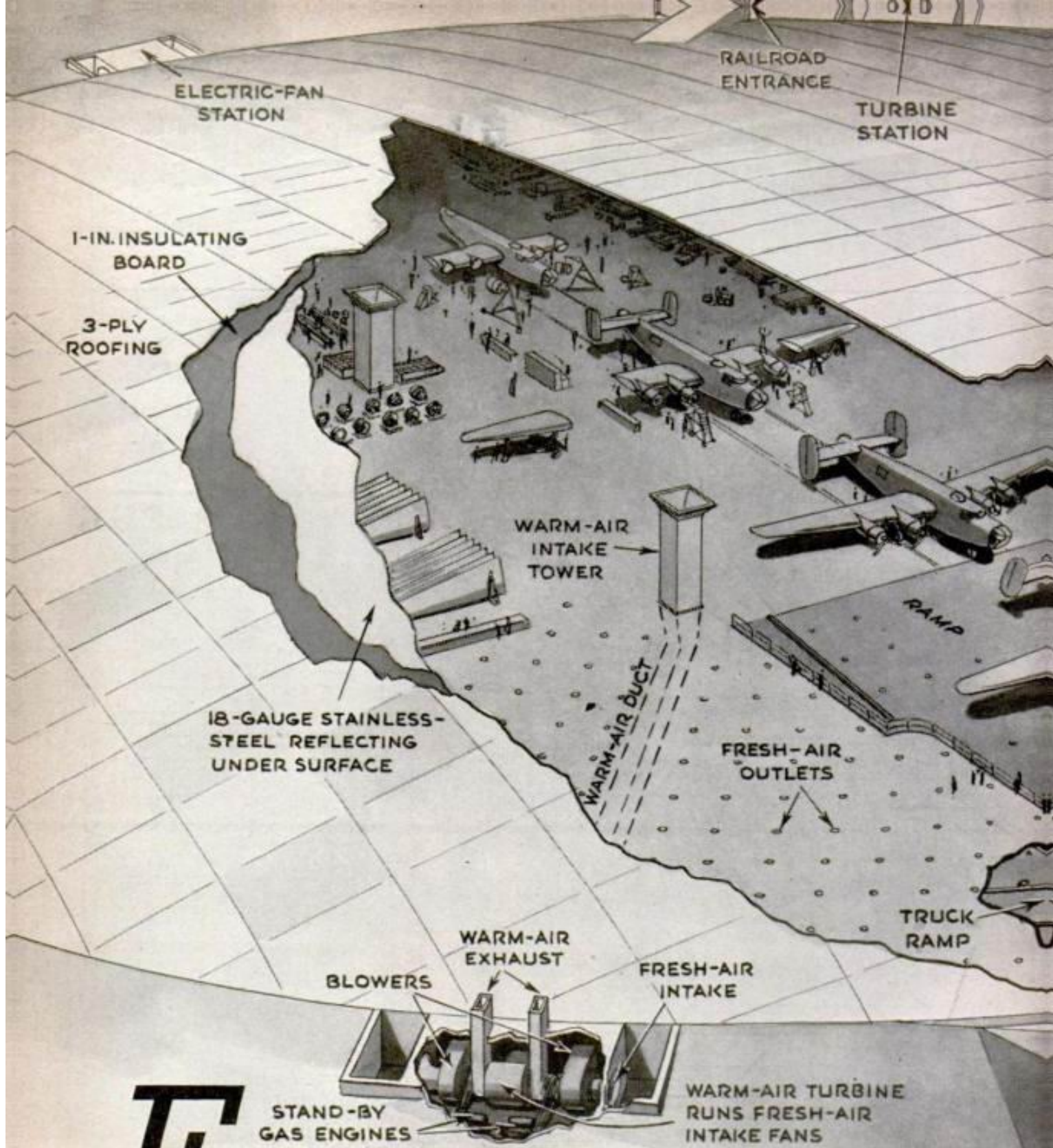
A steel shield that runs from the front wheels to the transmission protects the engine in rocky areas



Loads are dropped through hydraulically operated doors individually controlled from the driver's seat

EIGHTY tons of dirt and rock can be carried over rough ground and highways at speeds from two to 40 miles an hour in this gigantic "muck mover" built by Six Wheels, Inc., of Los Angeles. A 225-hp. engine pulls the 11-ton trailer, which is 51 feet long and stands 10 feet high. The walking beams illustrated below reduce road shocks and insure full traction for all wheels.

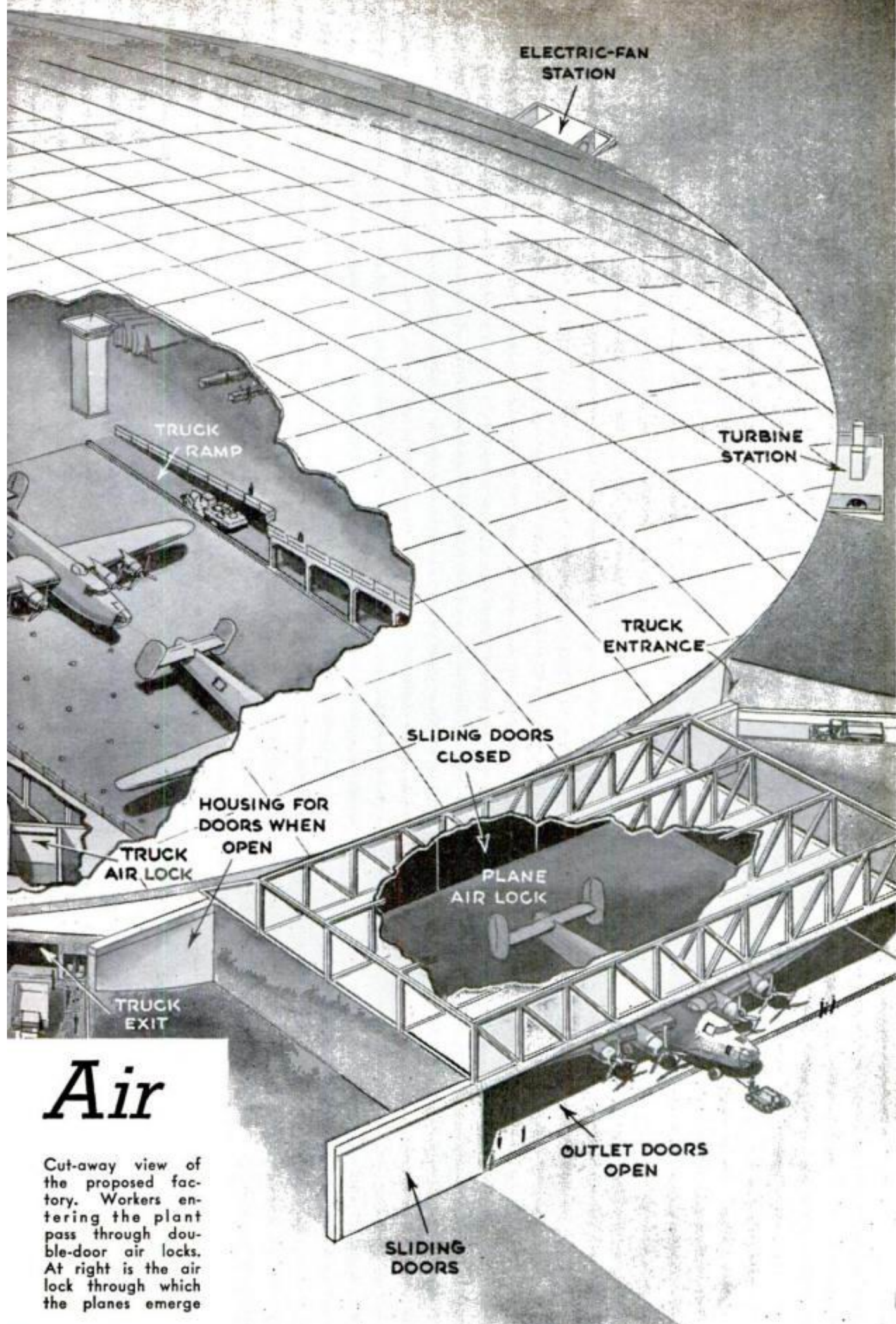




*F*actory Roof Floats on

TO ELIMINATE the columns and trusses that obstruct production in conventional plants, consulting engineer Herbert H. Stevens, Jr., of New York City, has designed an airplane factory in which the circular roof, 1,200 feet in diameter, is supported by an air pressure of only one ounce above normal atmospheric pressure (14.7 pounds

per square inch at sea level). Sixteen fans and four exhaust towers provide ventilation in addition to the air pressure which, being low, will have little or no effect on the workers. Other advantages include quick construction, low operating cost, and the saving of vital materials. The roof will cover an unobstructed working area of 26 acres.

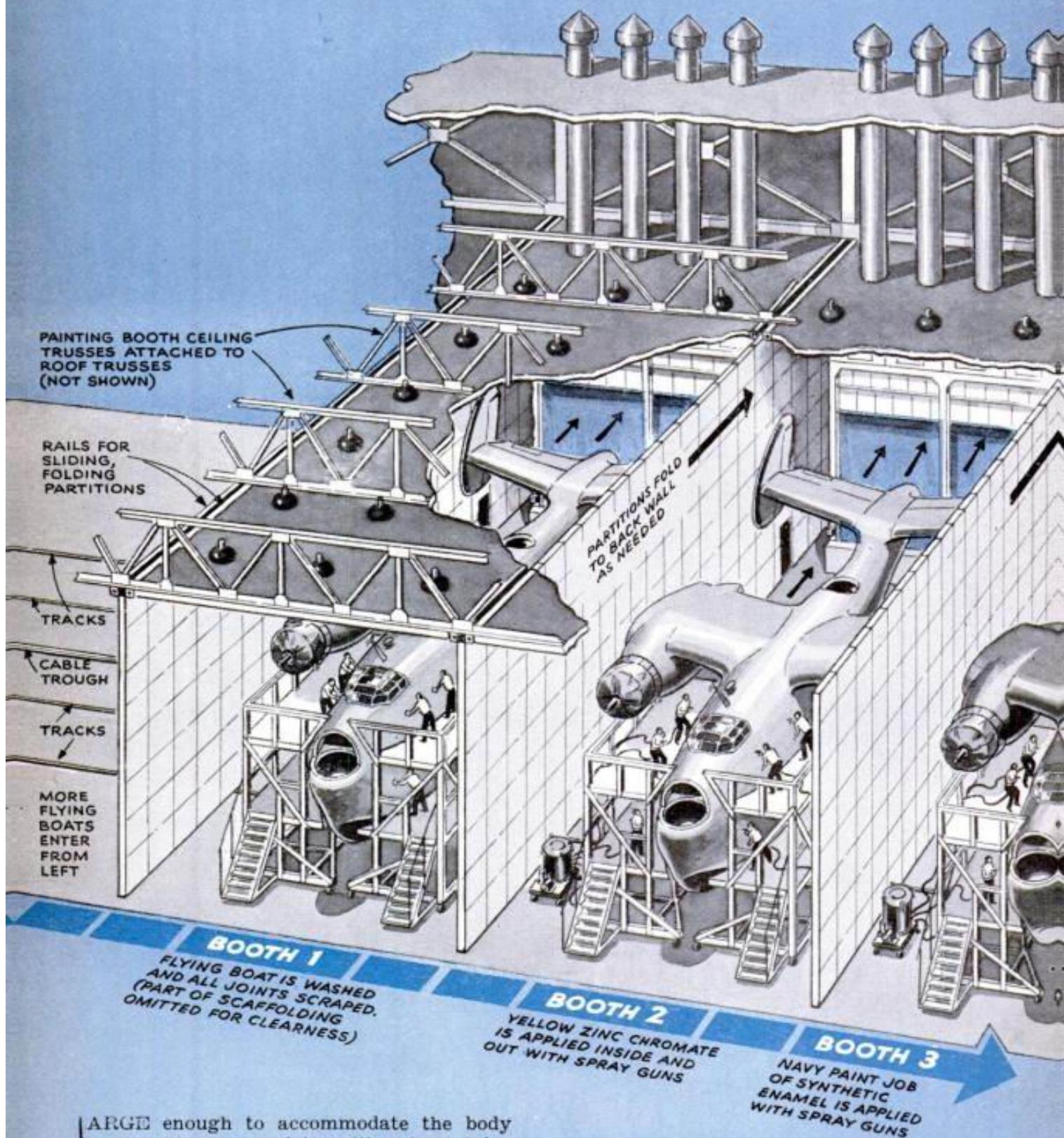


Air

Cut-away view of the proposed factory. Workers entering the plant pass through double-door air locks. At right is the air lock through which the planes emerge

APRIL, 1943

Painting the Big Planes



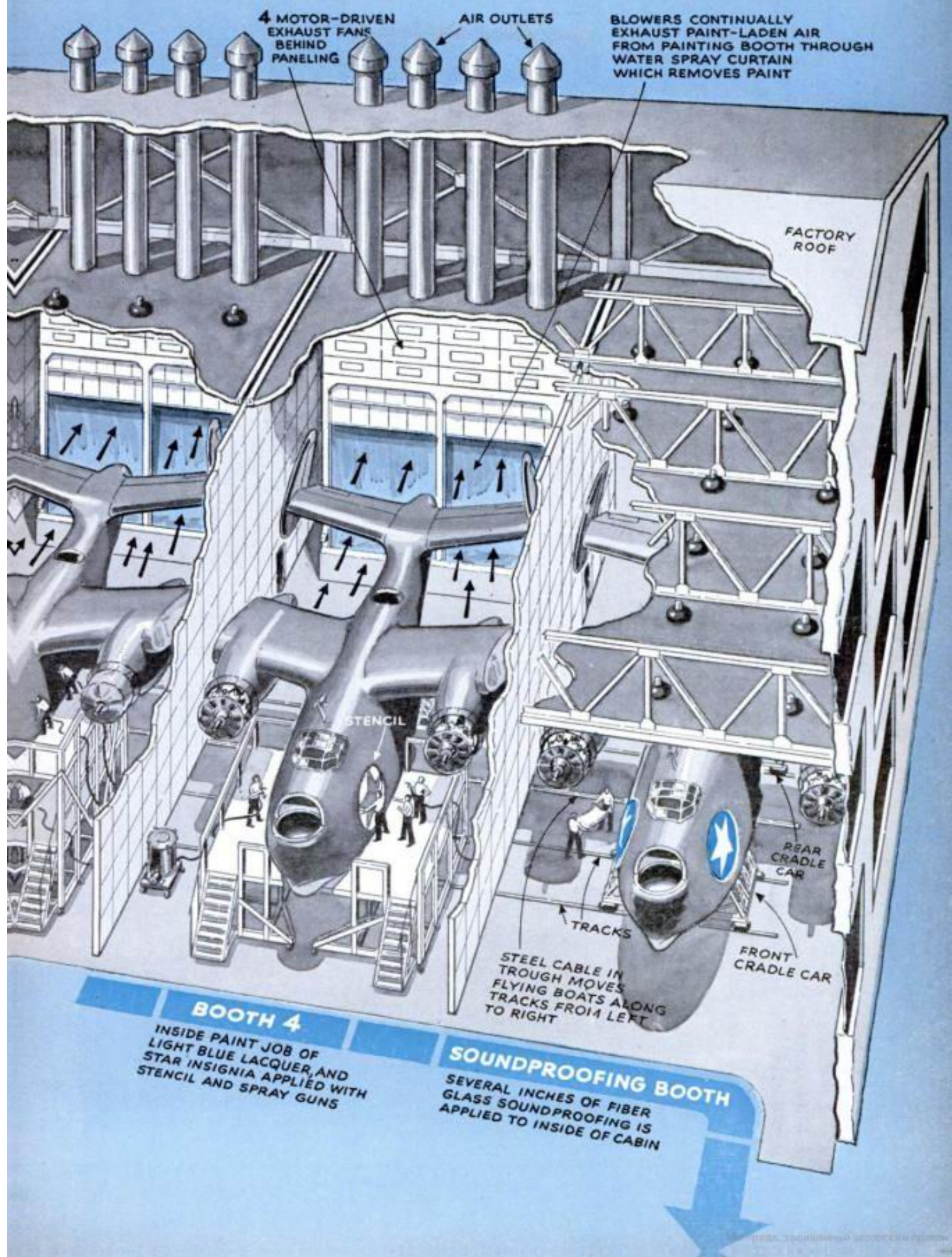
LARGE enough to accommodate the body structures, complete with wing stubs, engines, and tail assembly, of five big Navy patrol planes at once, a block-long shop in the Glenn L. Martin plant helps speed aircraft to the fighting fronts. As they move through the building-within-a-building, flying boats receive three paint jobs and two other finishing treatments in assembly-line style.

Each operation, performed in a separate booth, takes approximately the same time.

To assure this, men and women workers may be shifted as needed from one booth to another. When work in all booths is done, out comes a finished plane body at the end of the line.

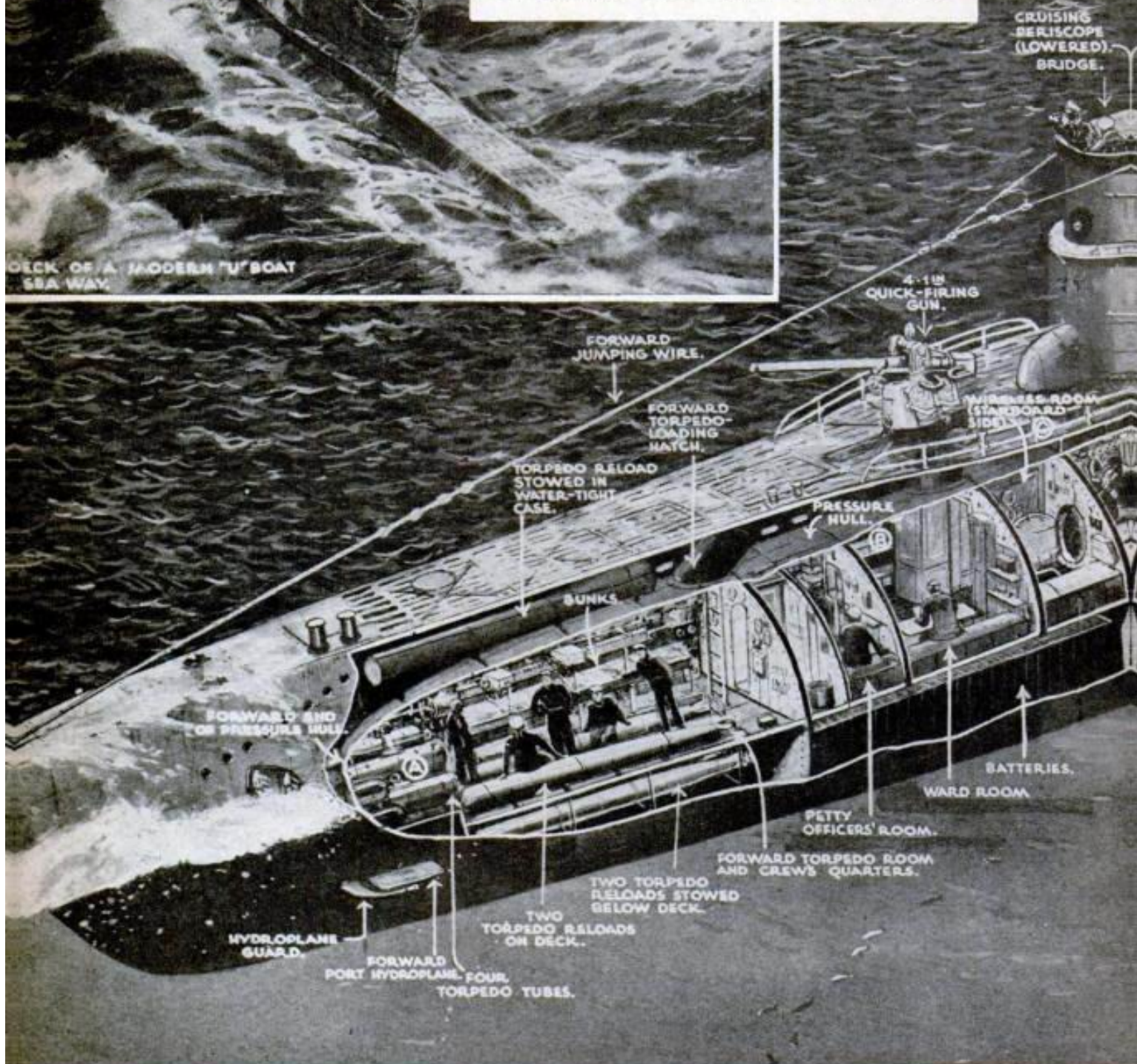
Now the whole scene shifts. Partitions, which have separated the booths, telescope toward the rear like the panels of folding household screens. This clears a pair of railway tracks running lengthwise through

World's Largest Spray Booth Works at Assembly-Line Speed



Cut-away view of the U-boat. A, forward torpedo room; B, ward room; C, hydrophone; D, control room; E and F, cruising and "attack" periscopes; G, galley; H, Diesel engine; I, electric motor

DECK OF A MODERN "U" BOAT
SEA WAY.



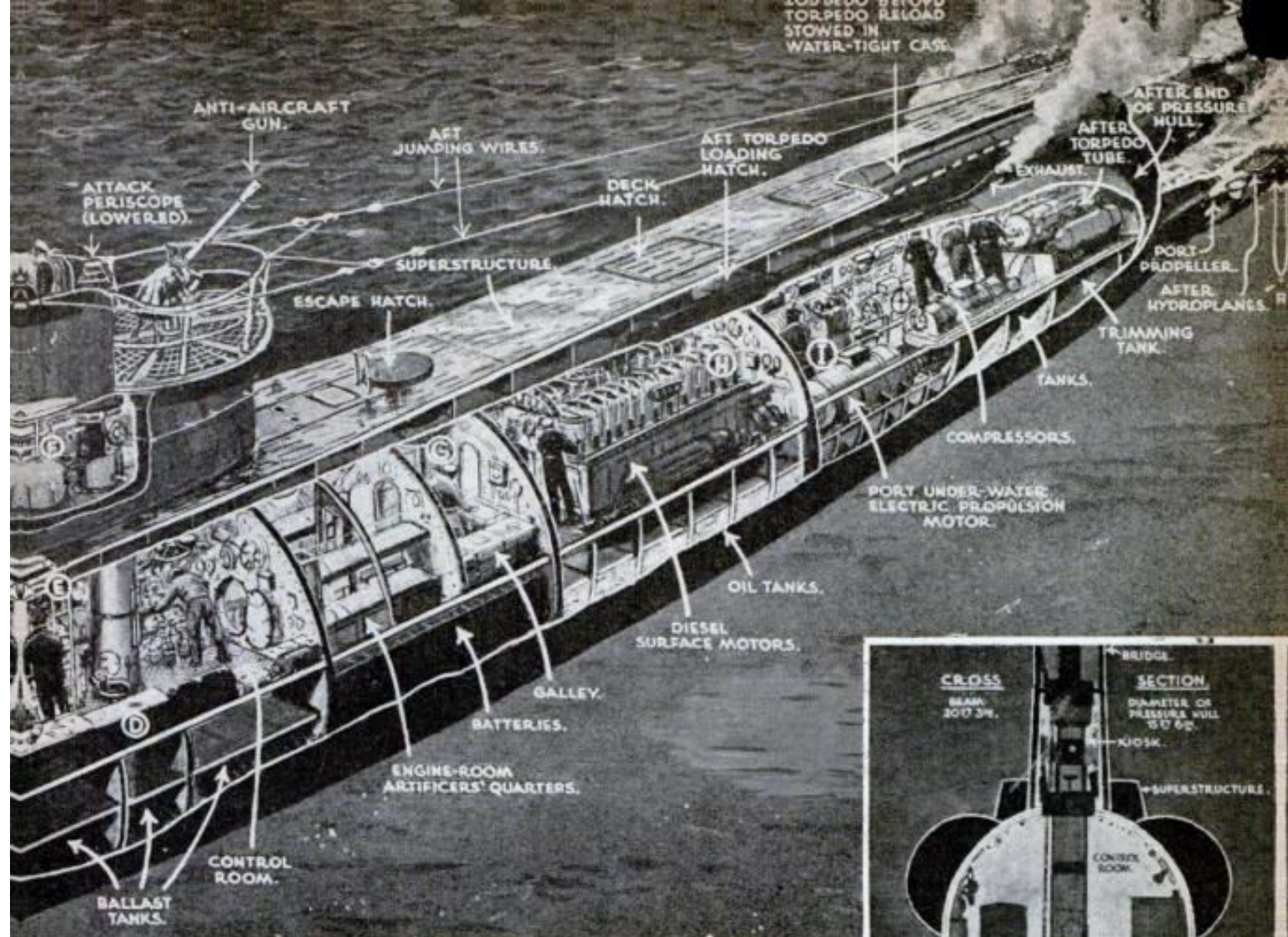
GERMAN UNDERWATER CRAFT ARE EQUIPPED FOR FINDING PREY,

angle eyepiece gives a broad view of the horizon to detect telltale smoke trails. Switching to a telescopic eyepiece then permits identification of a particular vessel.

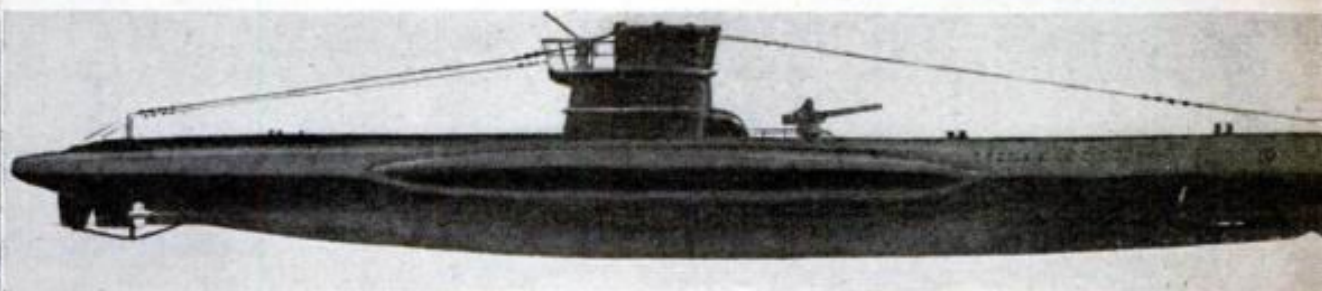
As the U-boat closes in on the ship, the commander takes his place at a massive, electrically driven "attack periscope," which he trains by foot controls. Without moving from his seat, he can ride it in a full circle. Through voice tubes, he issues steering and firing orders to the men below.

An additional aid to the underwater raider, a multi-unit hydrophone detects the beat of a distant ship's propellers. Red and green lights, appearing on a graduated dial of this sensitive instrument, betray the position of the surface ship. This permits the periscopes to be retracted, in clear weather when their wake would be visible, and enables the submersible to make its attack while completely under the surface.

By special permission of the Admiralty,



The cross section and side view of the submarine show the efficient design of the true or pressure hull, high bulges, superstructure, conning tower, and ballast tanks. Note the "kiosk" in the bridge structure; it is typical of these German boats. The vessel has twin propellers and rudders

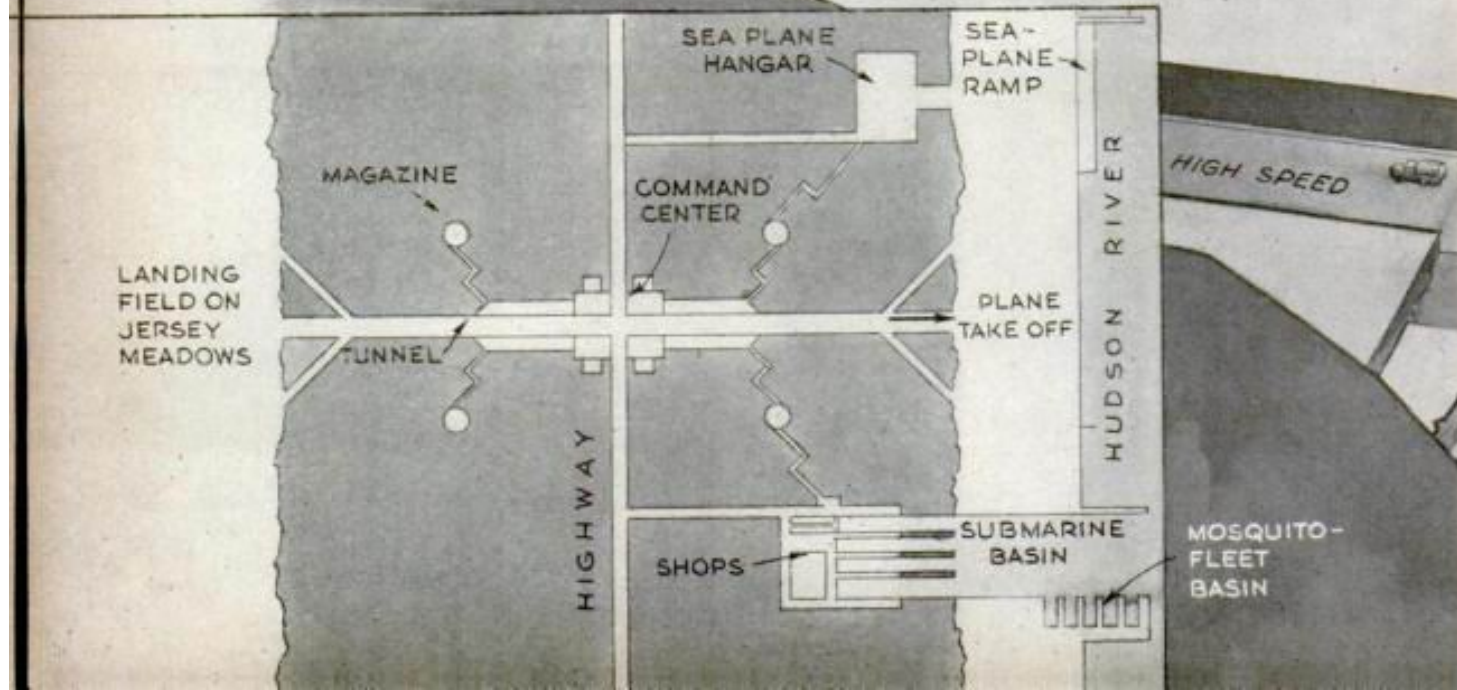
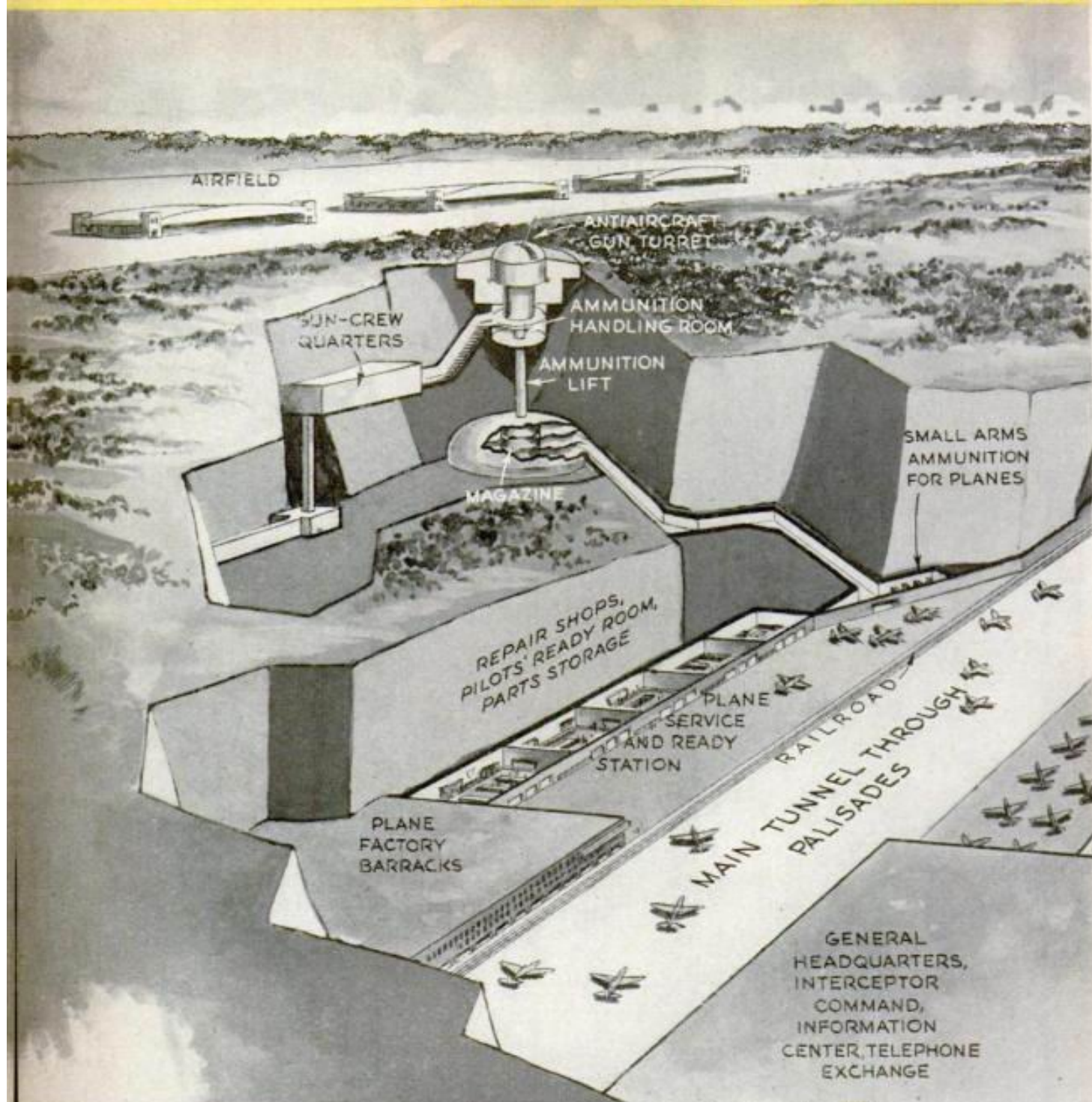


STALKING IT DOWN, AND FOLLOWING THROUGH FOR THE KILL

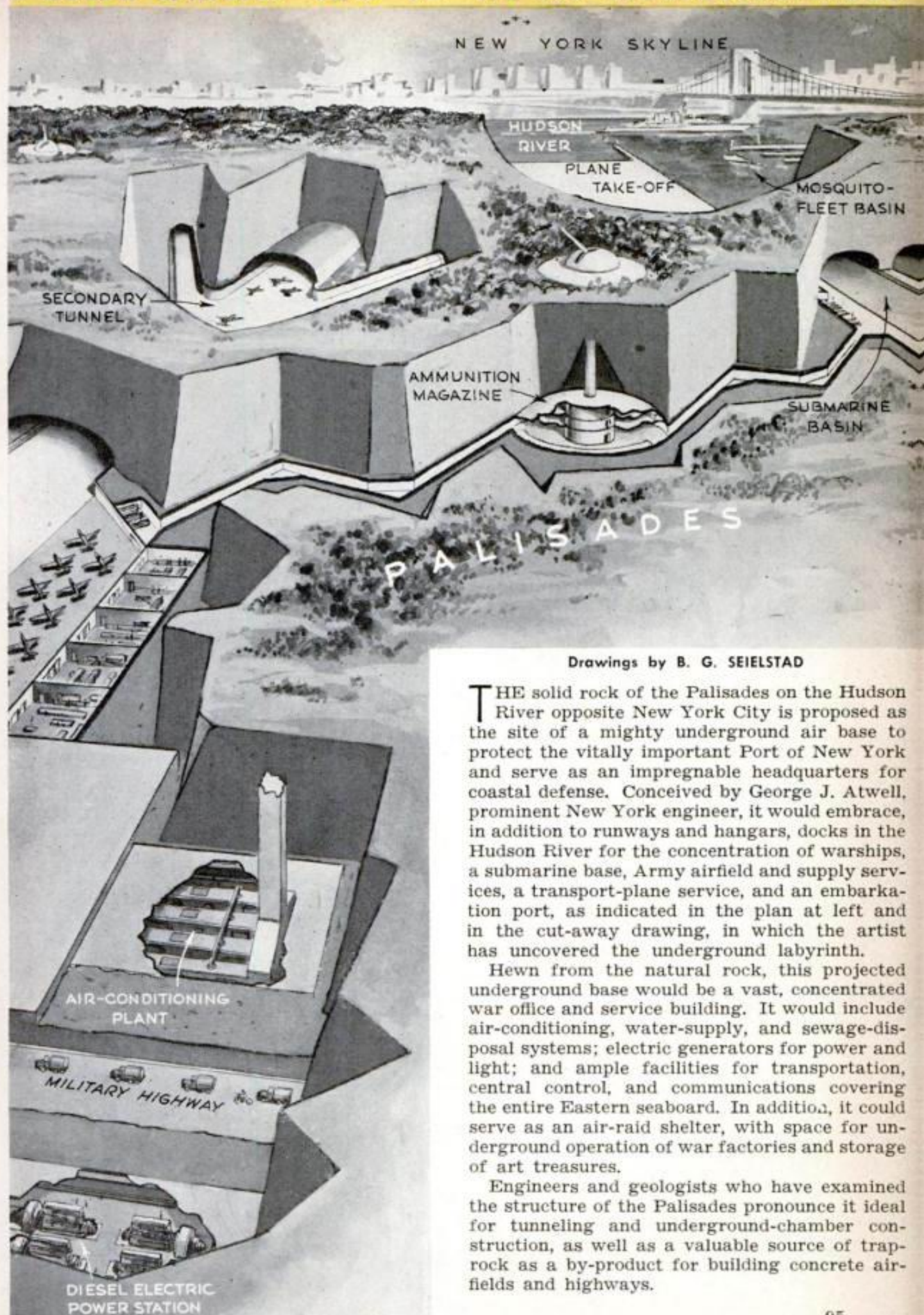
The forward torpedo room serves also as crew's quarters. Torpedo tubes are in the background, torpedoes on the floor



ROCK-HEWN AIR BASE



PROPOSED AS A U. S. GIBRALTAR



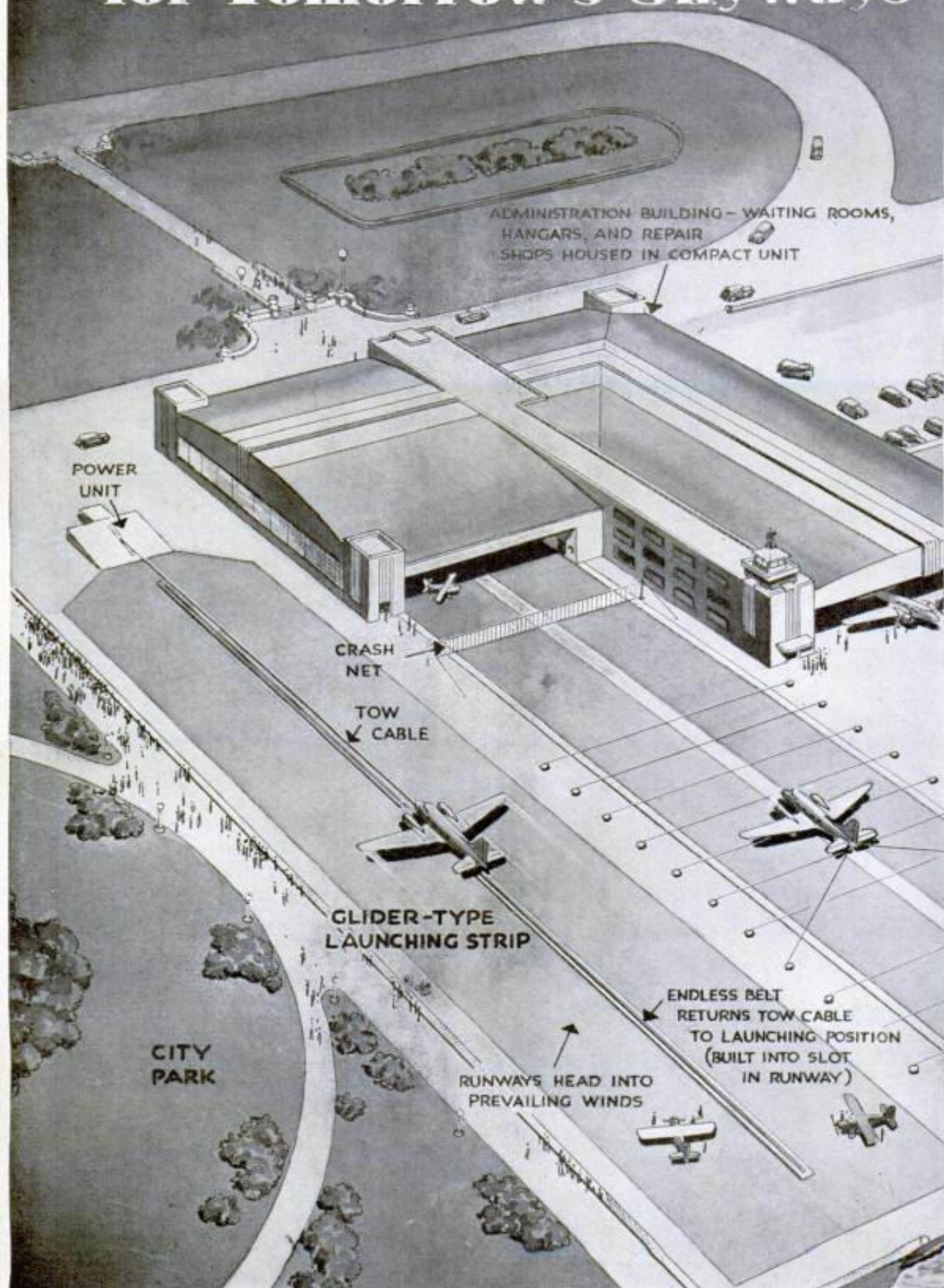
Drawings by B. G. SEIELSTAD

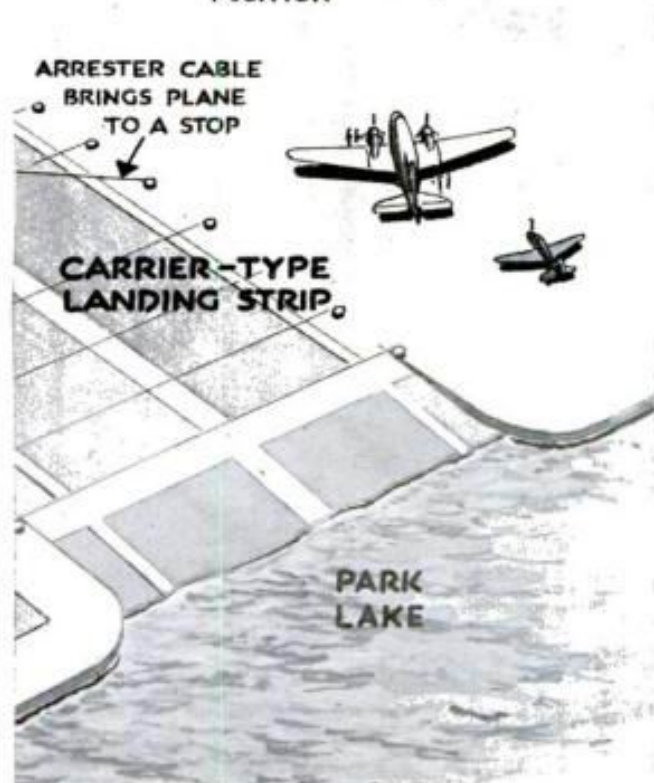
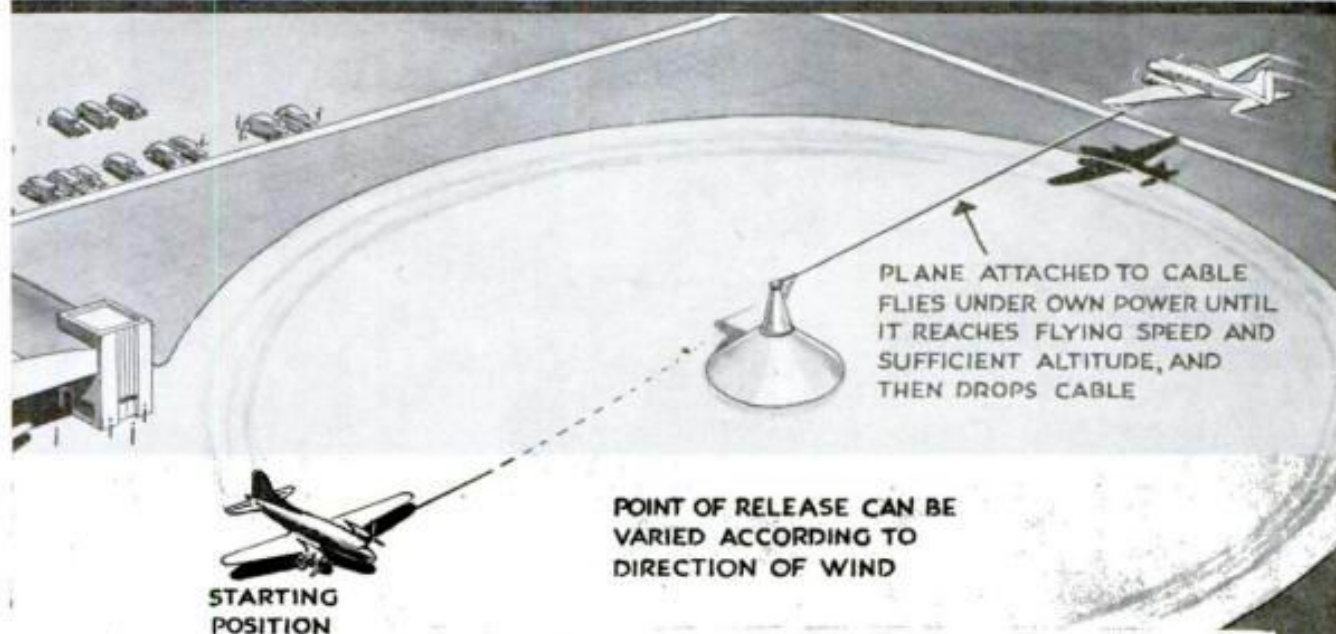
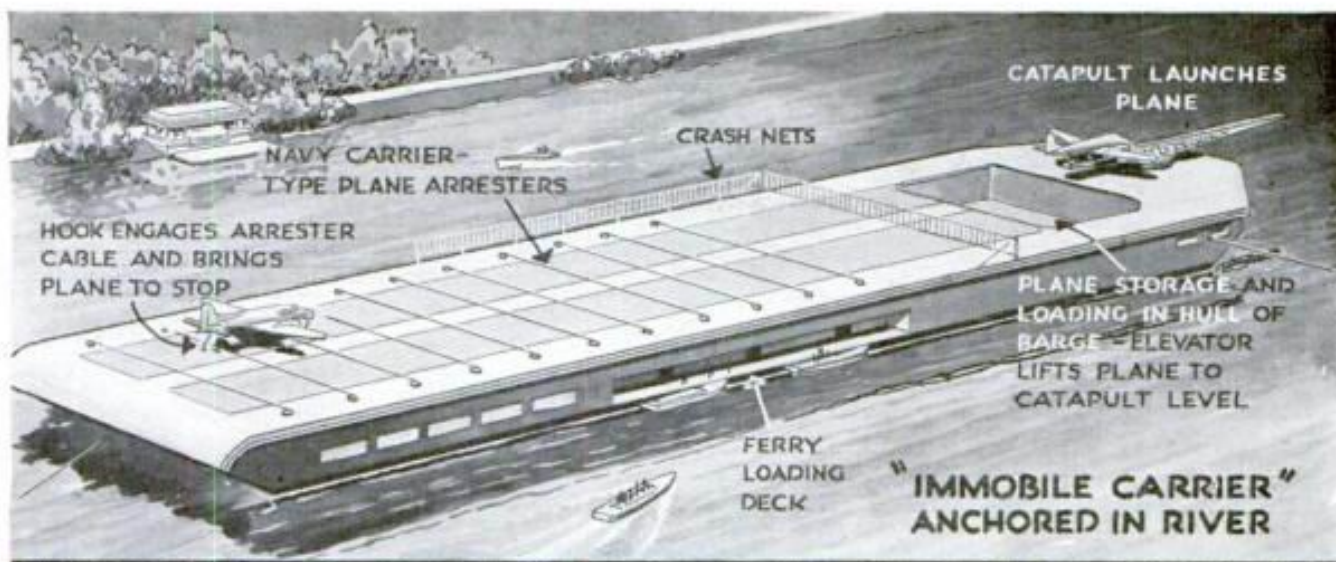
THE solid rock of the Palisades on the Hudson River opposite New York City is proposed as the site of a mighty underground air base to protect the vitally important Port of New York and serve as an impregnable headquarters for coastal defense. Conceived by George J. Atwell, prominent New York engineer, it would embrace, in addition to runways and hangars, docks in the Hudson River for the concentration of warships, a submarine base, Army airfield and supply services, a transport-plane service, and an embarkation port, as indicated in the plan at left and in the cut-away drawing, in which the artist has uncovered the underground labyrinth.

Hewn from the natural rock, this projected underground base would be a vast, concentrated war office and service building. It would include air-conditioning, water-supply, and sewage-disposal systems; electric generators for power and light; and ample facilities for transportation, central control, and communications covering the entire Eastern seaboard. In addition, it could serve as an air-raid shelter, with space for underground operation of war factories and storage of art treasures.

Engineers and geologists who have examined the structure of the Palisades pronounce it ideal for tunneling and underground-chamber construction, as well as a valuable source of trap-rock as a by-product for building concrete air-fields and highways.

Space-Saving Airports for Tomorrow's Skyways

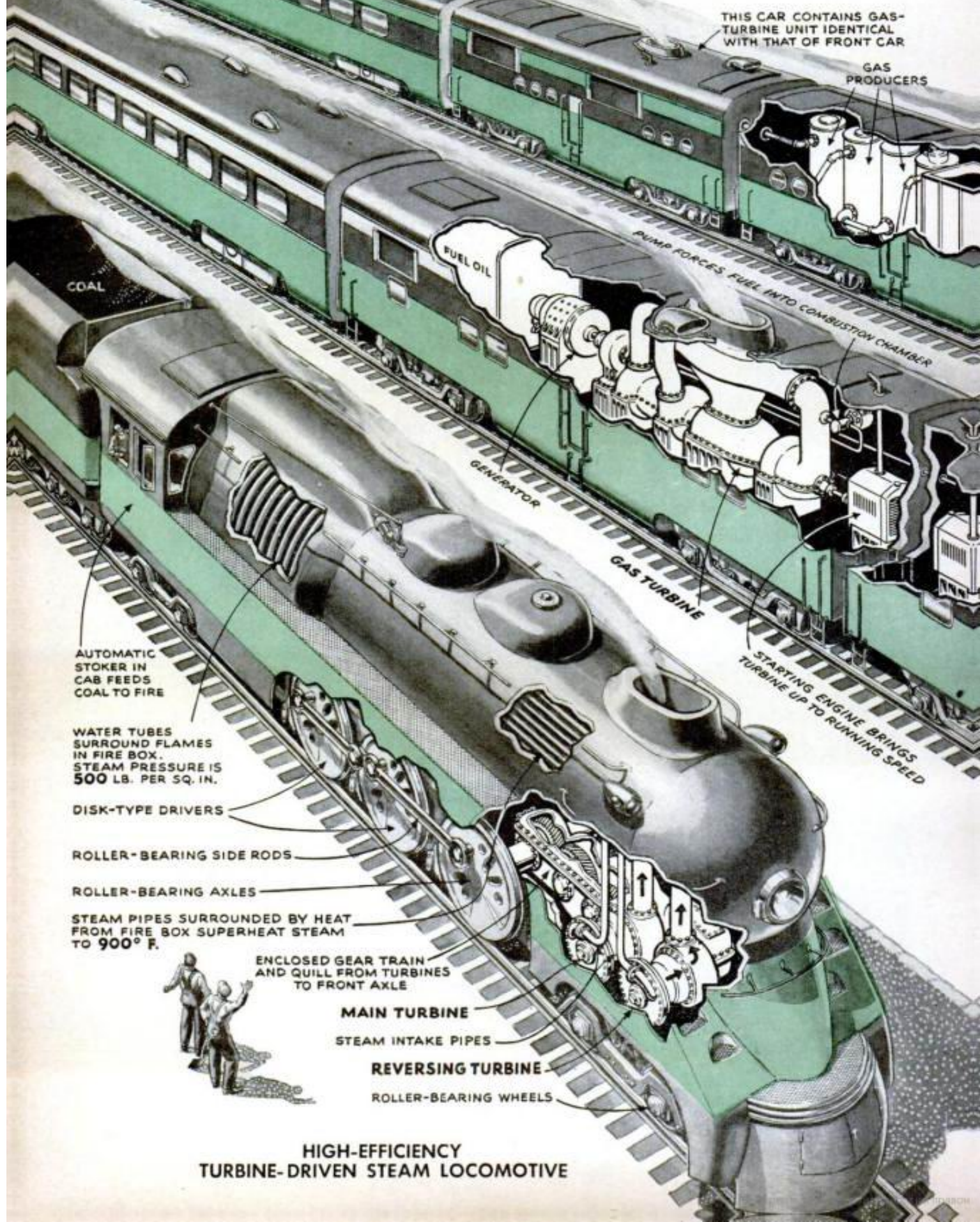




POSTWAR commercial airports will be models of compactness, efficiency, and safety, according to Andrew J. Fairbanks, professor of aeronautical engineering at Rensselaer Polytechnic Institute, Troy, N. Y., whose conception of tomorrow's airport is here illustrated. Long runways, expensive to build and maintain, will be obviated by catapults, circular take-offs, and flight-arresting gear, as well as by immobile "carriers" anchored in near-by rivers. Private flyers will use helicopters—and "parking lots." Any plane that can stand still in the air, be moved two feet this way, one foot that way, and parked like a car, is the ideal ship, says Professor Fairbanks, for hopping over to the village for supplies or taking the kids to the park for a picnic.

Drawings by B. G. SEIELSTAD

Postwar Locomotives Will Hit New High in Power and Efficiency



By CAPT. W. MACK ANGAS

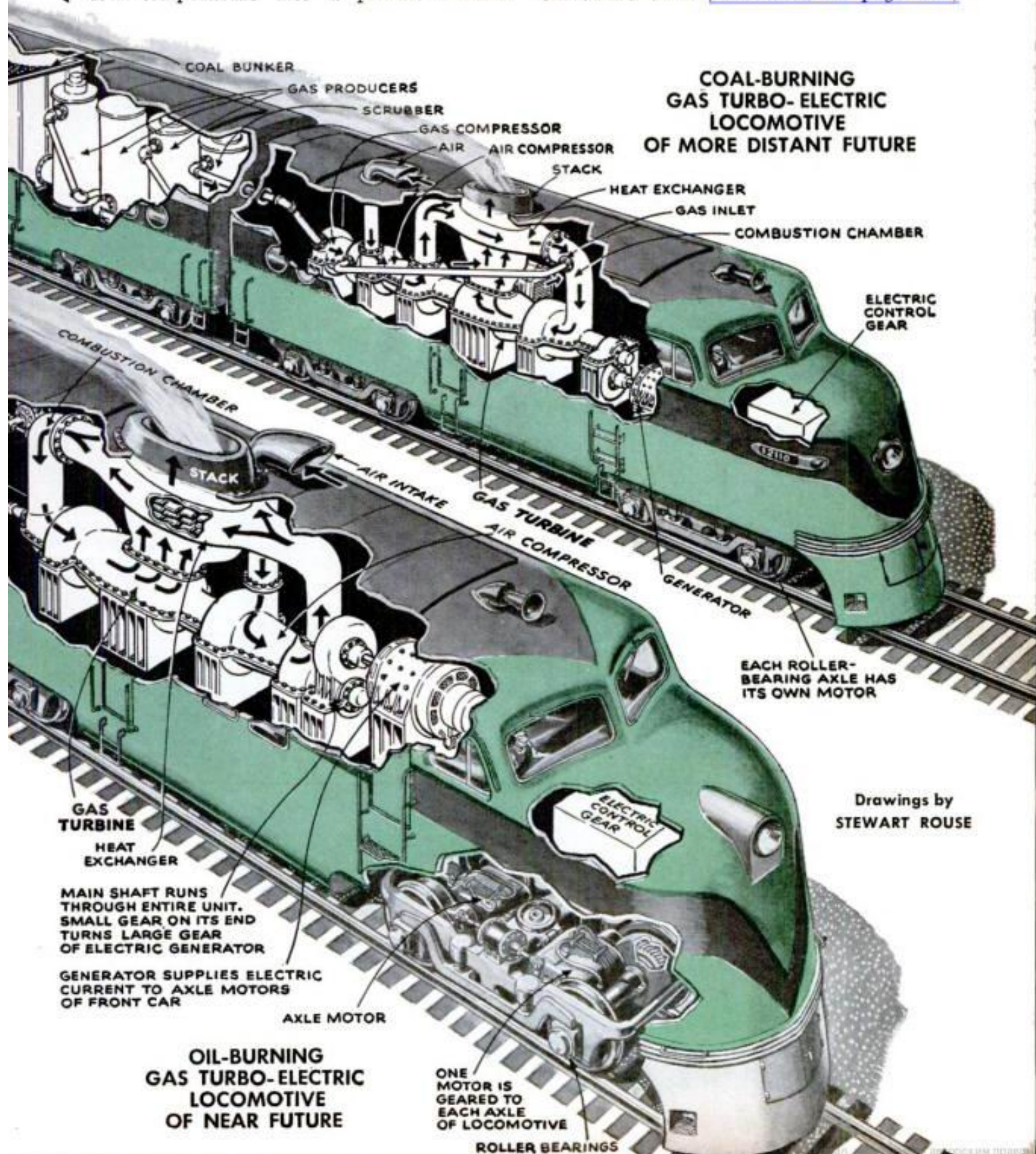
Civil Engineer Corps, U.S.N.

WHEN the new techniques and materials developed by the war are finally directed toward industrial problems of peacetime, one of the machines most likely to experience radical departures in design and construction is the railroad locomotive.

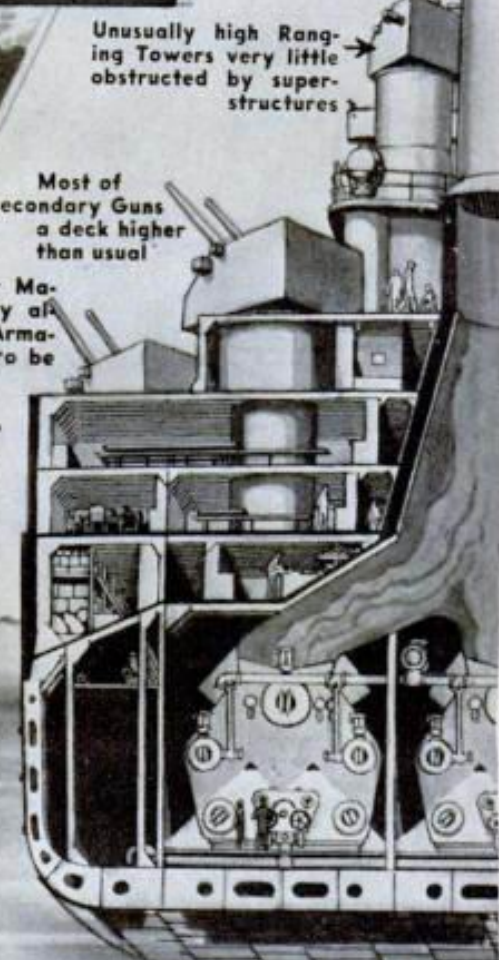
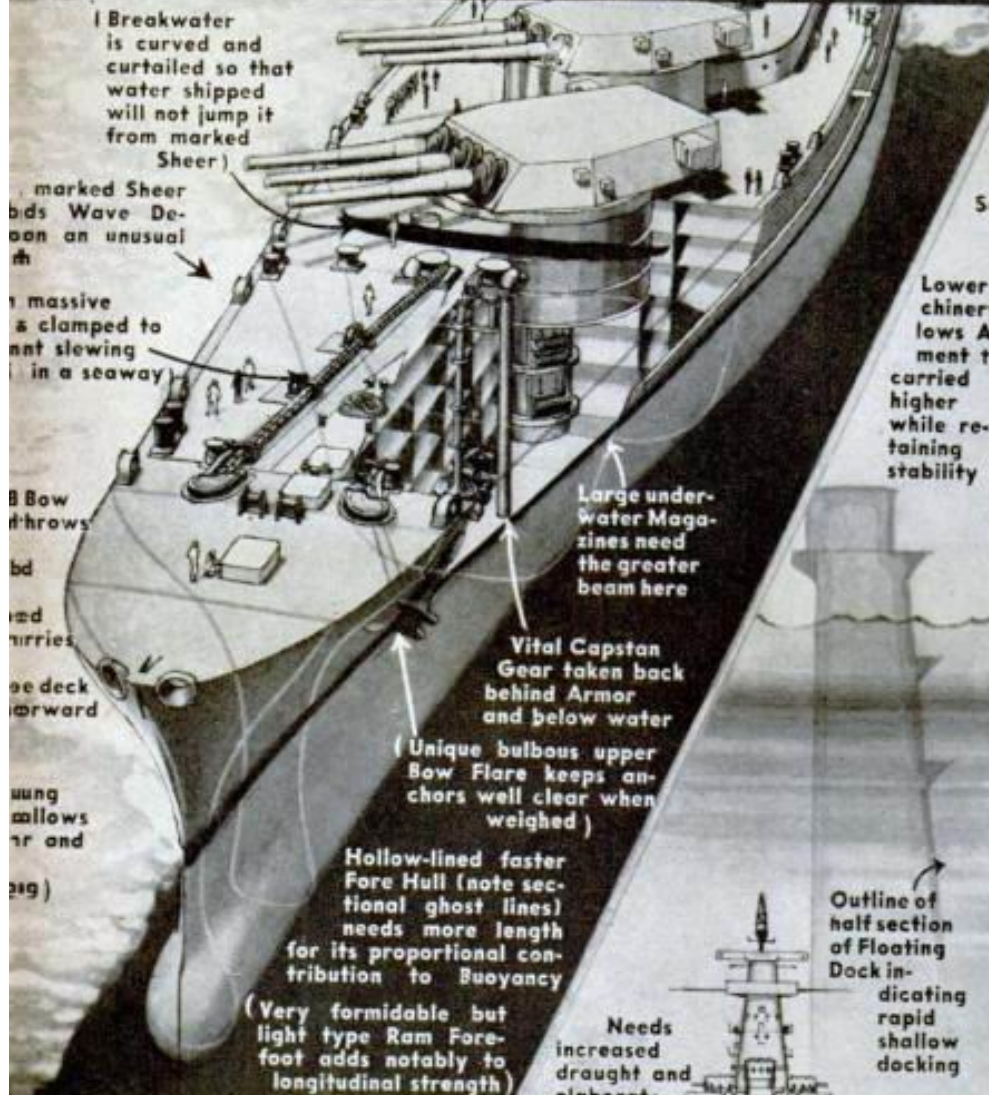
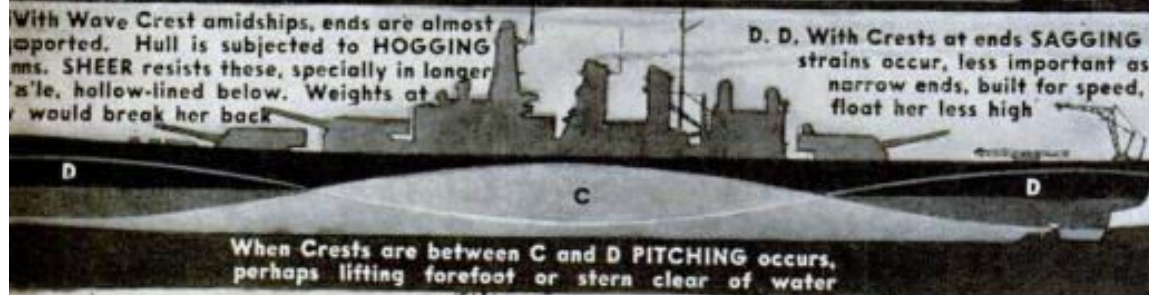
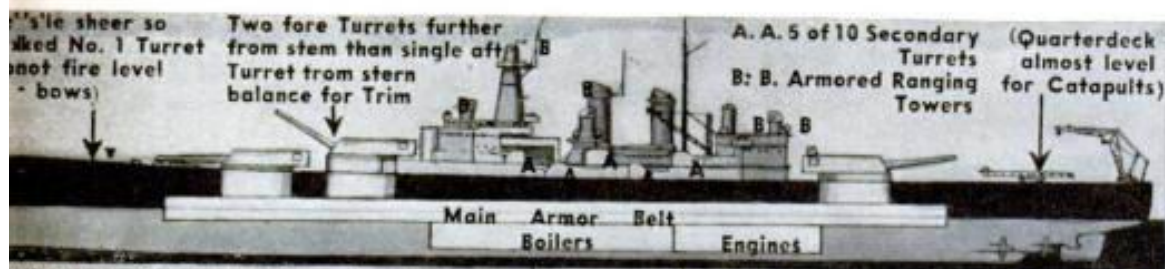
The familiar steam locomotive will still be with us for a while—but it, too, will undergo revolutionary changes. Air and water-cooled condensers that increase the efficiency of stationary and marine steam engines by permitting them to exhaust at low temperature into a partial vacuum

The opinions expressed in the following article are the author's, and should not be interpreted as those of any department of the Government.

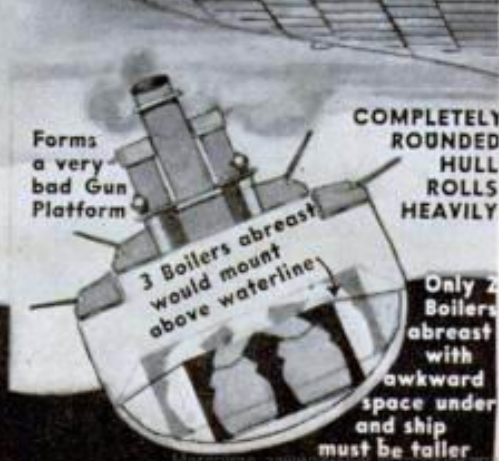
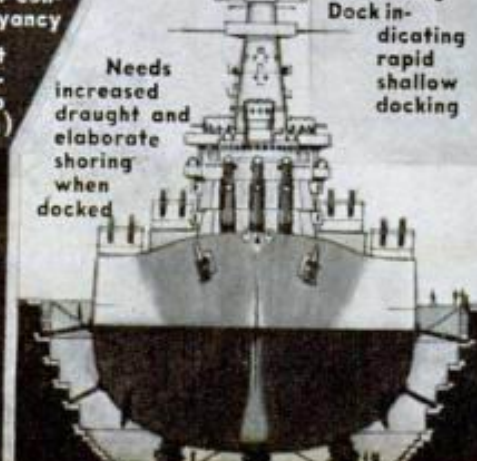
have, as yet, proved impractical for use on a locomotive. But there is no reason why the engine's efficiency cannot be increased by stepping up the pressure and temperature of the steam that drives it. A fire-tube boiler used in conjunction with a water-tube fire box, such as has already been developed, may readily raise current pressures of about 250 pounds per square inch to 400 or even 500 pounds—with a superheater to raise the steam's temperature from 600 to over 750 degrees F. Since steam much over the latter tem. *(Continued on page 210)*



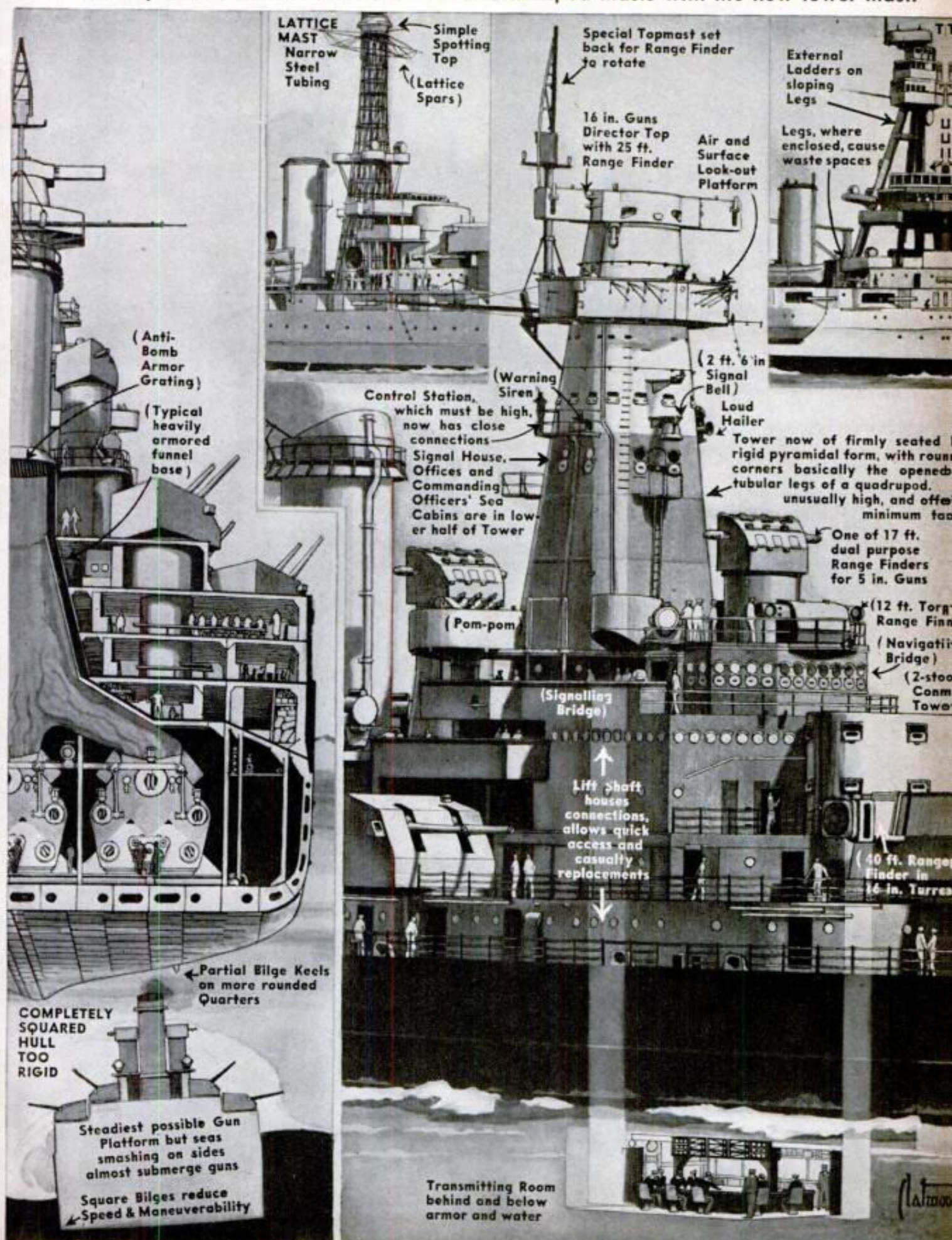
HOW A BATTLESHIP WORKS

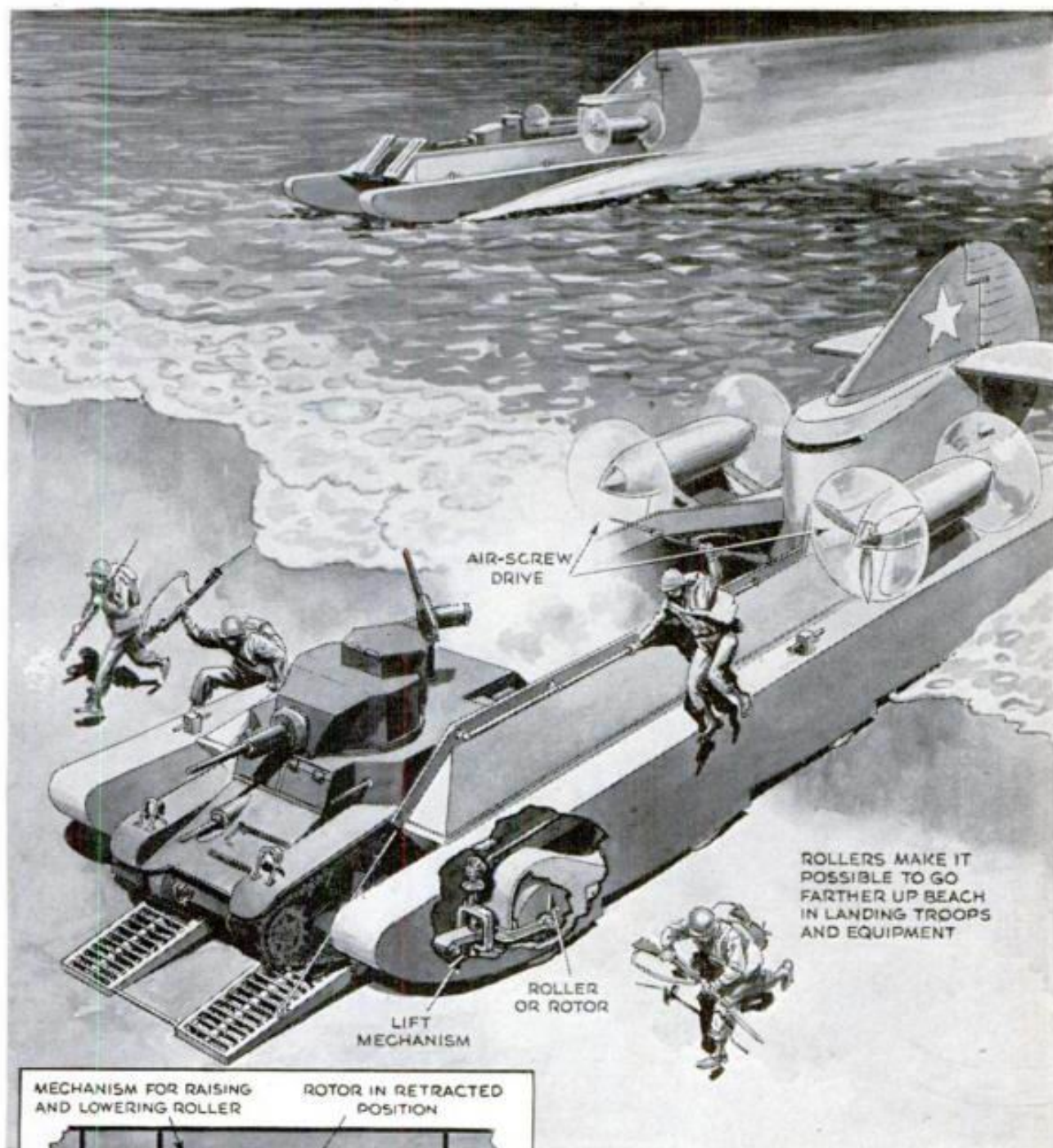


Equipment 1/50	Fuel 1/33
Machinery 1/8	Armament 1/7
Armor & Hull 2/3	



Where does a battleship's weight go? What kind of hull design should it have, and why? These and many other features of battleship design, as exemplified by the 35,000-tonners of our modern *North Carolina* class, are illustrated below by S. W. Clatworthy, noted British technician, in drawings from the "London Sphere." Insets directly below contrast outmoded lattice and tripod masts with the new tower mast.





Rollers Give Landing Boat High Speed

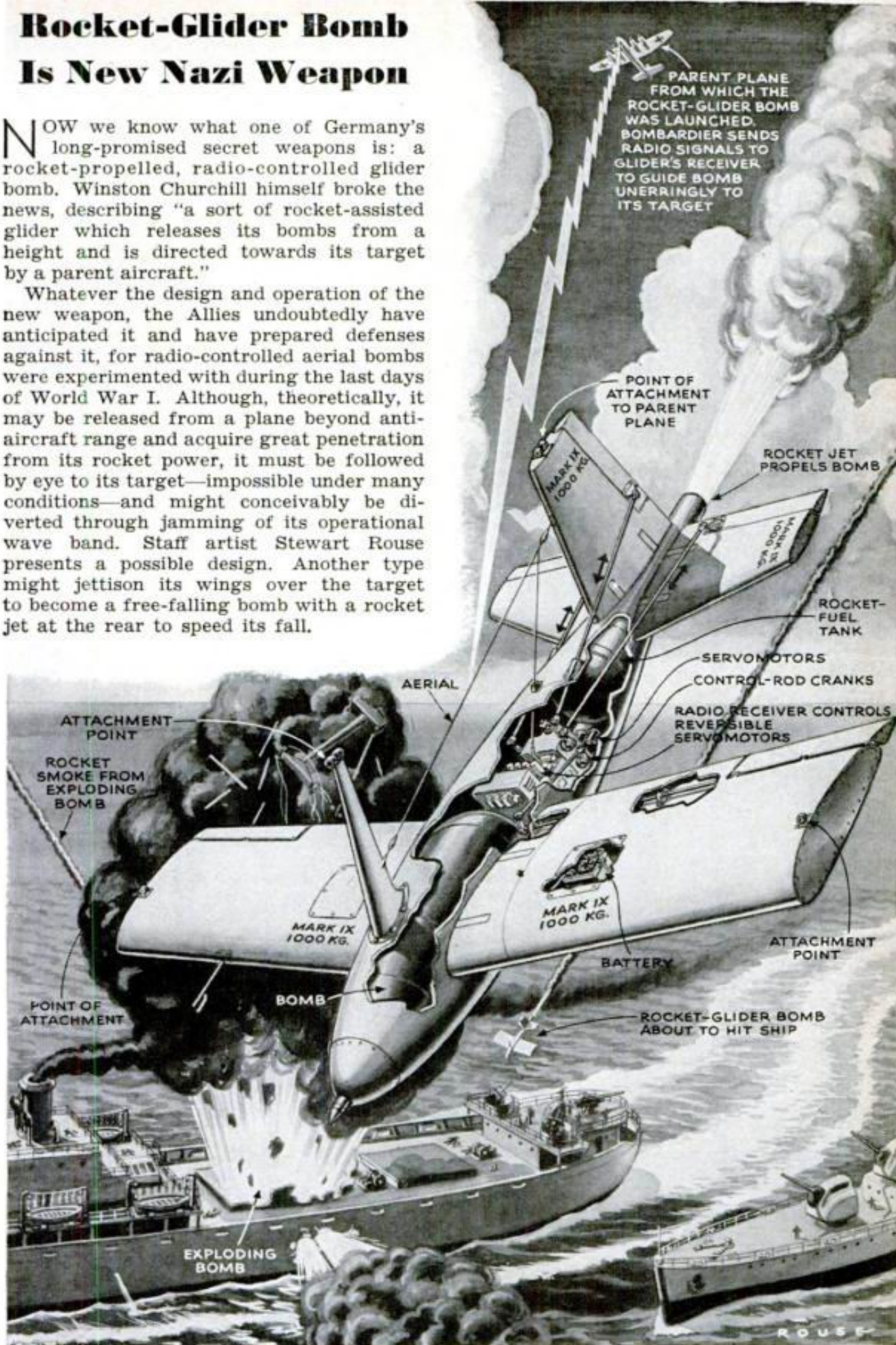
A HIGH-SPEED, air-propeller-driven boat that literally rolls over the waves has been proposed by Pietro C. Lombardini, of England. In starting, the boat moves through the water on its hull, but once it attains 50 knots, a series of free-turning rollers, lowered into the water in place of

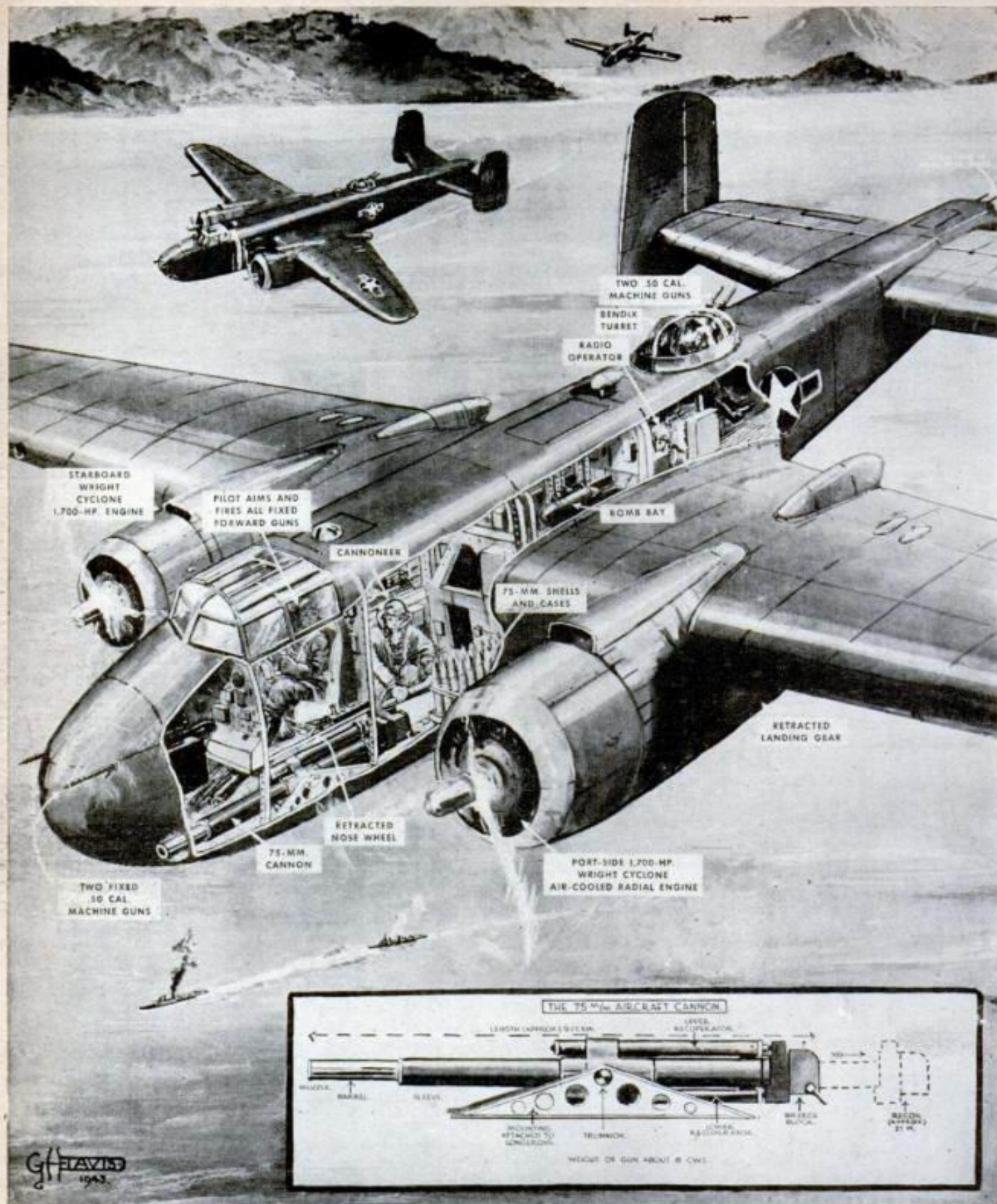
the hull, reduces the boat's resistance and enables it to increase its speed greatly. The drawing shows an adaptation for beach landings. As a small aircraft carrier, the fast ship would make it possible for planes to take off with a minimum run and to land at high speeds, the inventor claims.

Rocket-Glider Bomb Is New Nazi Weapon

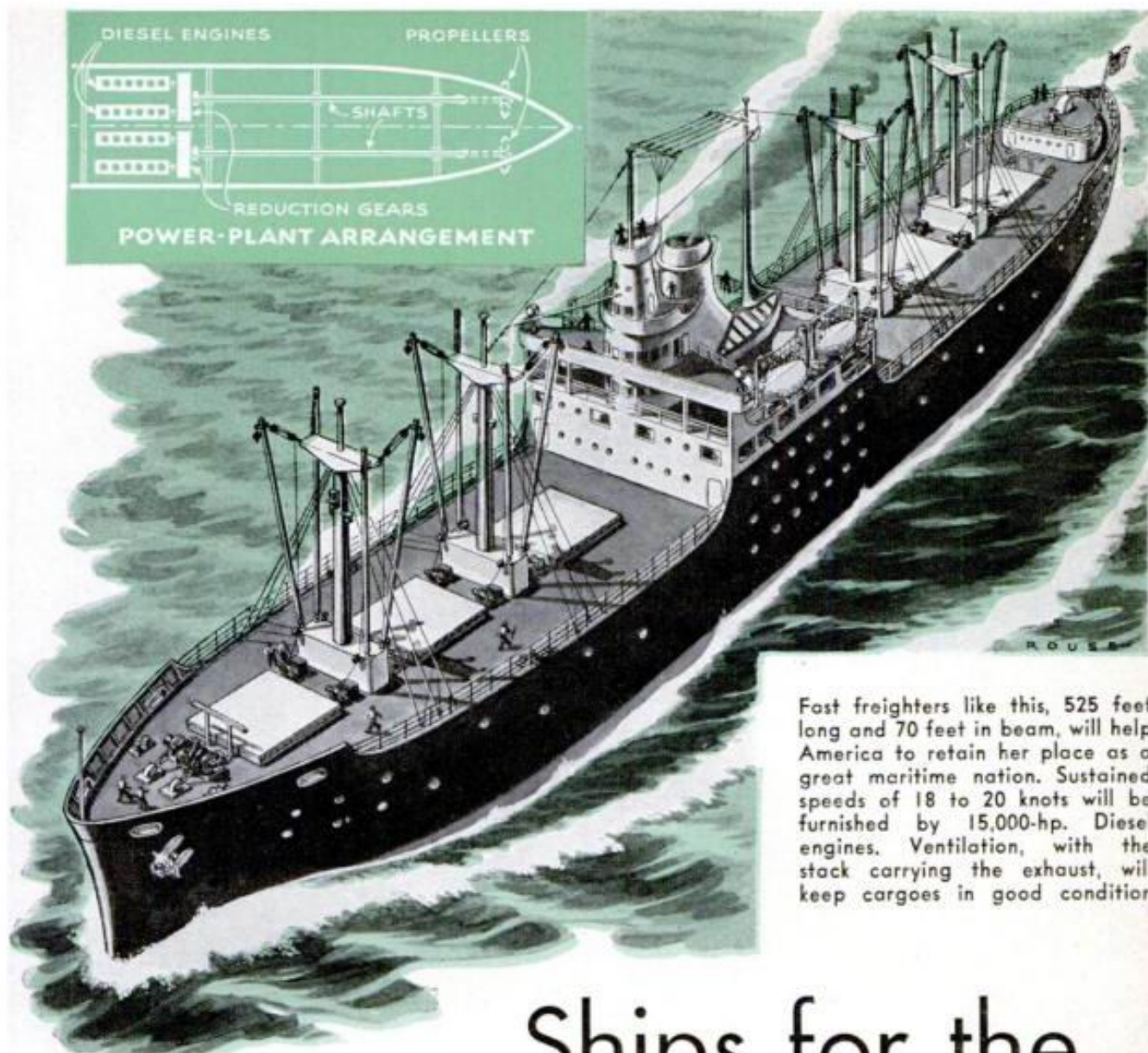
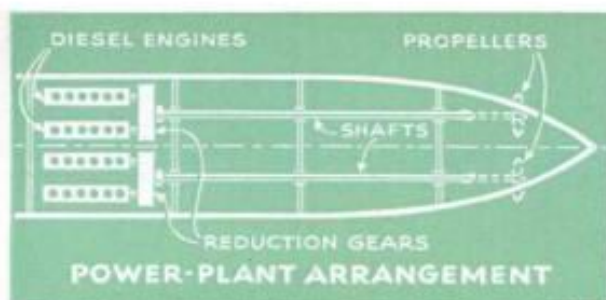
NOW we know what one of Germany's long-promised secret weapons is: a rocket-propelled, radio-controlled glider bomb. Winston Churchill himself broke the news, describing "a sort of rocket-assisted glider which releases its bombs from a height and is directed towards its target by a parent aircraft."

Whatever the design and operation of the new weapon, the Allies undoubtedly have anticipated it and have prepared defenses against it, for radio-controlled aerial bombs were experimented with during the last days of World War I. Although, theoretically, it may be released from a plane beyond anti-aircraft range and acquire great penetration from its rocket power, it must be followed by eye to its target—impossible under many conditions—and might conceivably be diverted through jamming of its operational wave band. Staff artist Stewart Rouse presents a possible design. Another type might jettison its wings over the target to become a free-falling bomb with a rocket jet at the rear to speed its fall.





Artillery Grows Wings . . . How the world's biggest aerial gun is mounted in the North American Mitchell B-25 medium bomber (P.S.M., Feb. '44, p. 105) is shown in this drawing by G. H. Davis from the Illustrated London News. Mounted beside the pilot, with its muzzle protruding from the lower left of the new metal nose section, the 75-millimeter cannon is loaded by a special crew member. Like the other fixed forward guns, it is aimed and fired by the pilot.



Fast freighters like this, 525 feet long and 70 feet in beam, will help America to retain her place as a great maritime nation. Sustained speeds of 18 to 20 knots will be furnished by 15,000-hp. Diesel engines. Ventilation, with the stack carrying the exhaust, will keep cargoes in good condition

Ships for the Seas of Peace

By CAPT. W. MACK ANGAS (C.E.C.) U.S.N.

Drawings by STEWART ROUSE

Opinions expressed in the following article are the author's. They should not be interpreted as those of any branch or department of the Government.

ALONG with being the leading industrial power at the close of the war, the United States will also be a great maritime nation. With a fleet of medium-sized cargo vessels, tankers, and cabin liners as fine as or finer than any others afloat, our early postwar merchant fleet will lack only express superliners and will be fitted to carry its share of trade in the first days of peace.

To remain a great maritime nation, however, we must be prepared to construct improved vessels when science and industry return to normal. At that time materials and techniques that have been devoted to the war will enable shipbuilders to turn out vessels far surpassing those now in existence.

The most spectacular and highly publi-

cized merchant ships are the express superliners, and if transocean planes do not take too much of their trade, larger and faster ones will be built. Those operated before the war were of over 50,000 tons. Their speed, averaging 28 knots on a crossing, made it possible to maintain weekly service between New York and Europe with two ships.

Postwar superliners will be still faster, but probably will not exceed 32 or 33 knots, although it is estimated that 35 knots could

be used advantageously to allow longer periods for victualing, fueling, and cleaning ship. Over-all length will be kept to 1,100 feet and beam to 120 feet by channel, terminal, and docking limitations.

Propulsion will almost undoubtedly be by quadruple screws driven by geared turbines. Pressures as high as 1,200 pounds are likely, and steam temperatures may be raised by superheating to as much as 900 degrees Fahrenheit. Also possible are geared Diesel engines, Diesel-electric drive, and the recently developed mercury-steam turbo-electric system.

Cabin liners will suffer much less from air competition. Larger and more comfortable than even the finest of the prewar ships of this type, they will probably have a length

of 800 feet or more, with docking facilities in many of the cruise ports visited in the "off season" of the North Atlantic service. The power plant needed for their maximum speed of 24 or 25 knots will perhaps not exceed 60,000 or 70,000 horsepower, and their normal sea speed of 21 or 22 knots will be sustained with considerably less. For this, geared Diesel engines and Diesel-electric drive are much more probable than for the huge power outputs required for a superliner capable of over 30 knots.

By far the most important merchant ships are freighters. The finest yet produced are possibly the handsome and able C-3 ships of the United States Maritime Commission, and new ones will be in all likelihood a development of this type. World-

CABIN LINER

LENGTH 800 FT.
BEAM 100 FT.
POWER 60,000 HP
SPEED 25 KNOTS

TWIN SCREWS

SUPERSTRUCTURE
OF SHOT-WELDED
STAINLESS STEEL

ALL LIFEBOATS HAVE DIESEL
ENGINES AND RADIOS

QUADRUPLE
SCREWS UNDER
STERN

SUPERLINER

LENGTH 1,100 FT.
BEAM 120 FT.
POWER 250,000 HP
SPEED 33 KNOTS

SHATTERPROOF
GLASS WINDOWS

DIESELS EXHAUST
UP STACK

AIR DUCTS AND
FANS IN DUMMY
STACK

LARGE,
OPEN DECKS
FOR CRUISE SERVICE

AFTER BOILER-
ROOM STACK

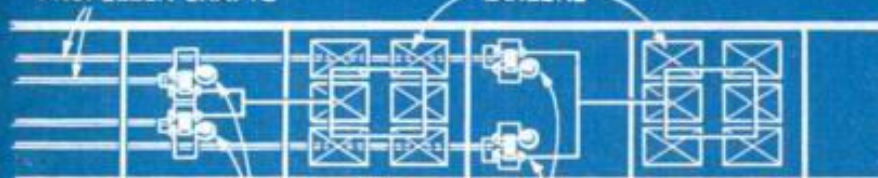
FORWARD BOILER-
ROOM STACK

PROPELLER SHAFTS

BOILERS

TURBINES AND REDUCTION GEARS

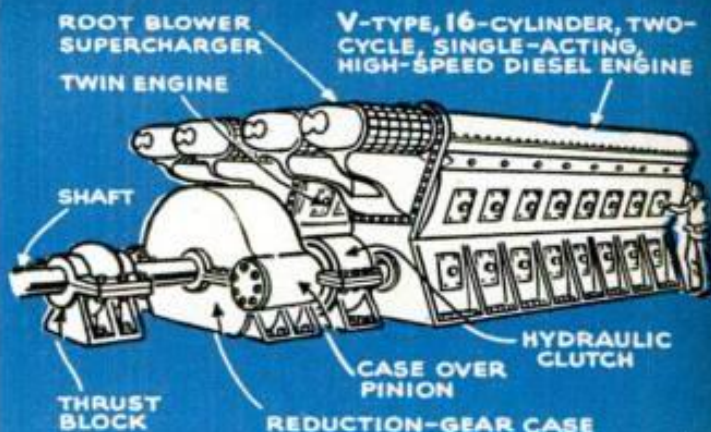
SUPERLINER POWER-PLANT ARRANGEMENT



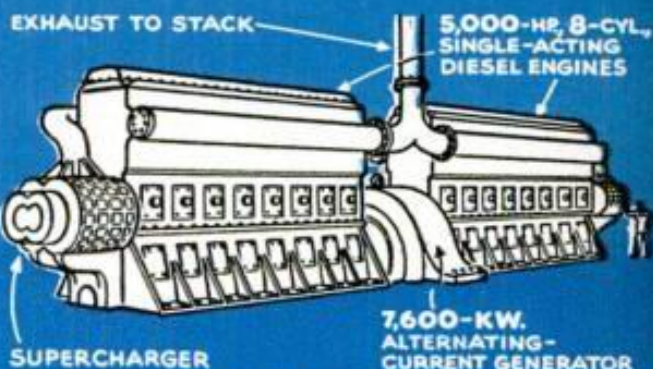
wide war improvements to channel, harbor, terminal, and docking facilities will permit lengths of 500 or even 525 feet. Sustained speeds as high as 18 or 20 knots may be expected.

Geared Diesel engines of about 15,000 total horsepower driving twin screws will probably propel the majority of these freighters, though undoubtedly some will employ high-pressure steam plants, and the internal-combustion, or "gas," turbine in conjunction with electric transmission is a possibility. It is also likely that the slightly higher efficiency of the single screw in ships of moderate size may lead to its utilization in services where the greater reliability and shallower draft made possible by twin screws are not necessary.

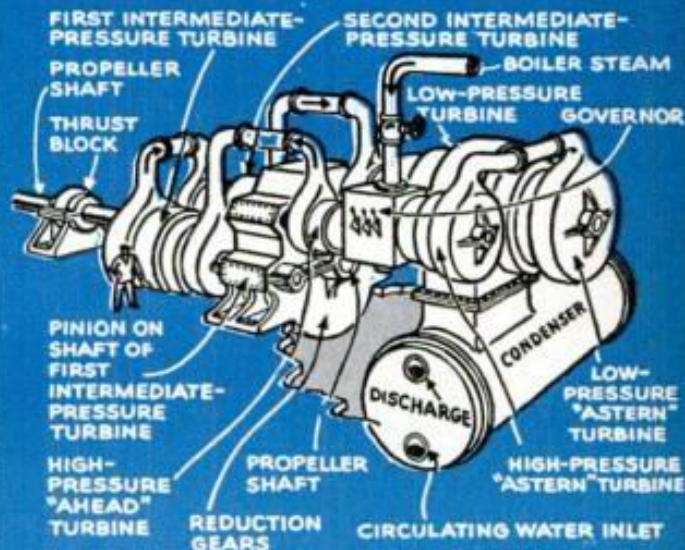
POWER-PLANT UNITS



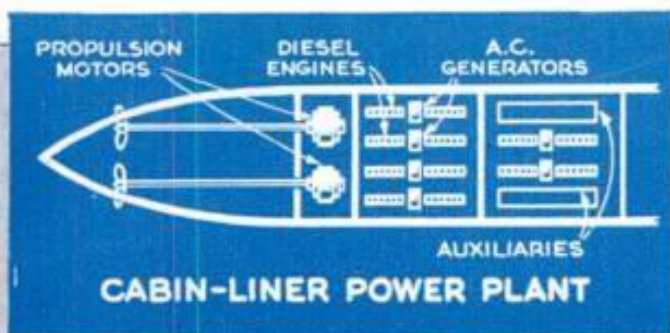
ONE OF THE TWO POWER UNITS, TWIN-SCREW FREIGHTER



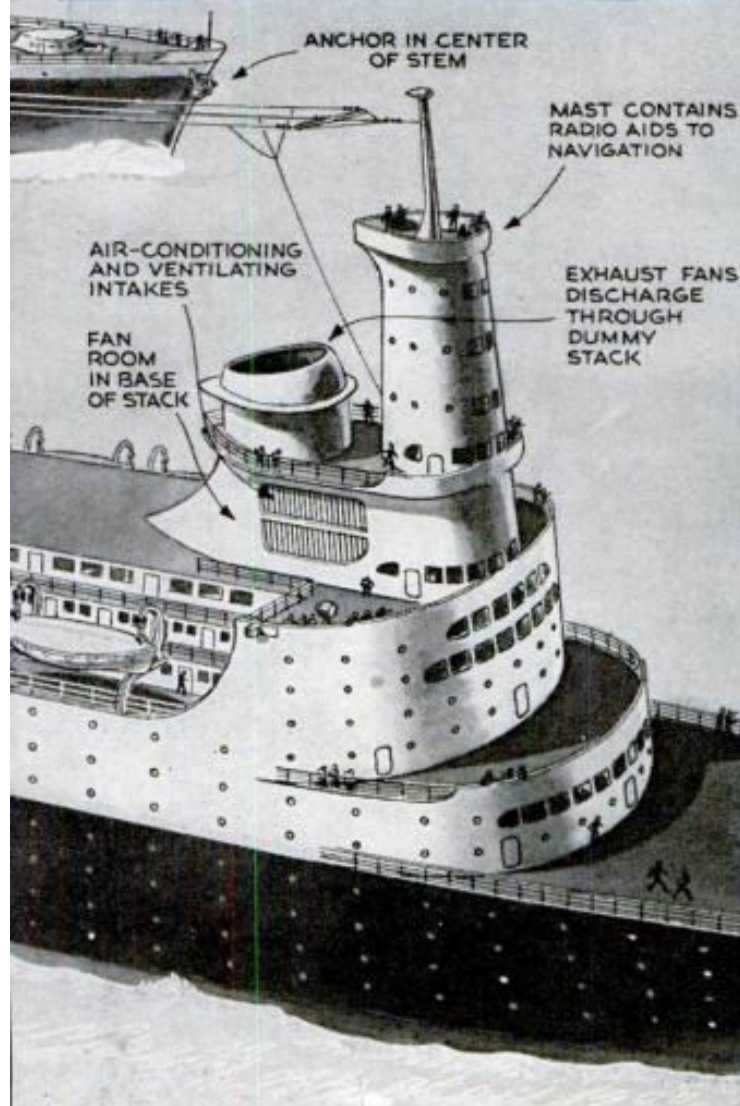
ONE 10,000-HP POWER UNIT, DIESEL-ELECTRIC CABIN LINER



QUADRUPLE-EXPANSION SINGLE-REDUCTION-GEARED TURBINE UNIT. FOR SUPERLINER

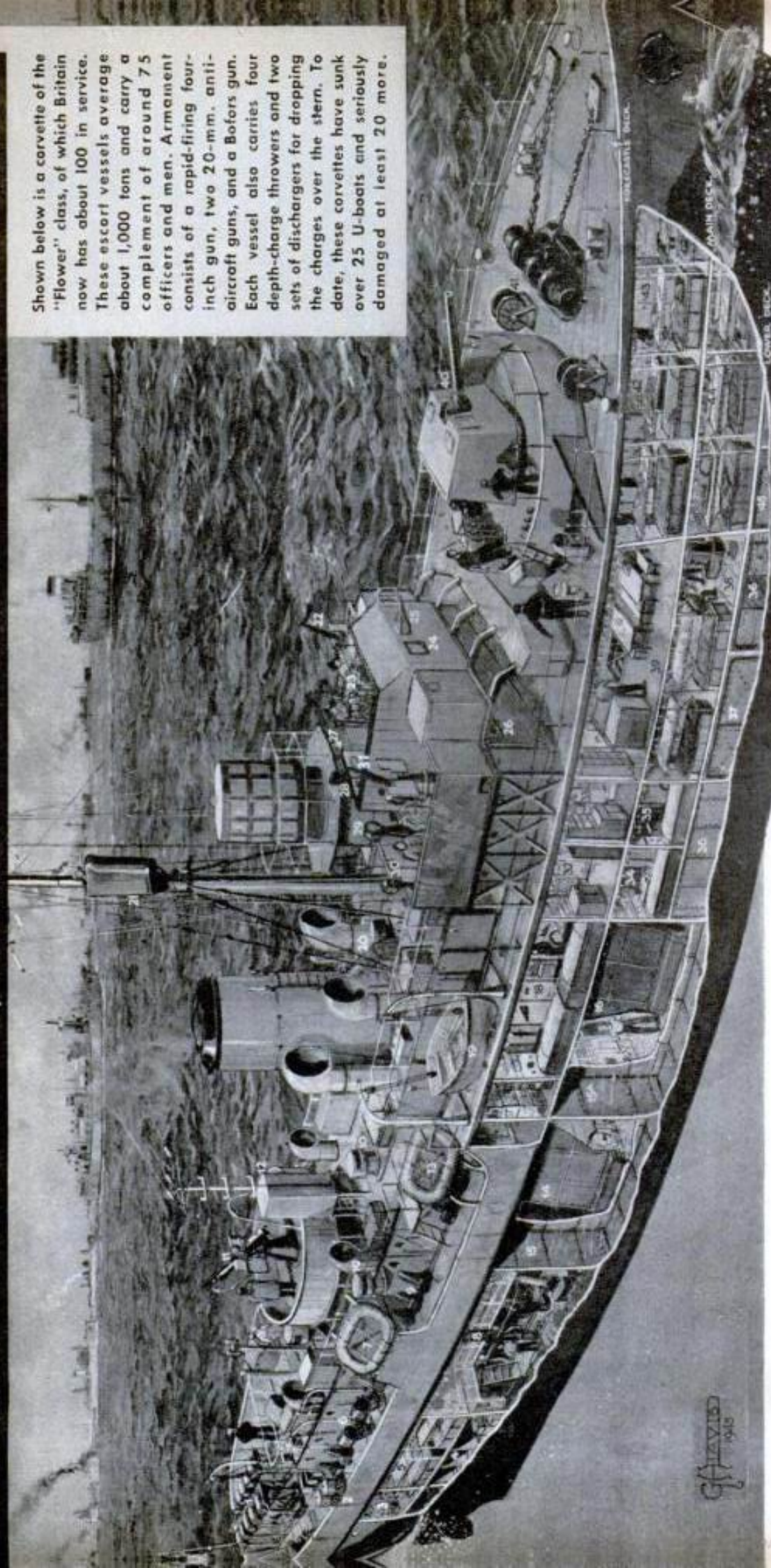


CABIN-LINER POWER PLANT



ANCHOR IN CENTER OF STEM

Shown below is a corvette of the "Flower" class, of which Britain now has about 100 in service. These escort vessels average about 1,000 tons and carry a complement of around 75 officers and men. Armament consists of a rapid-firing four-inch gun, two 20-mm. anti-aircraft guns, and a Bofors gun. Each vessel also carries four depth-charge throwers and two sets of dischargers for dropping the charges over the stern. To date, these corvettes have sunk over 25 U-boats and seriously damaged at least 20 more.



- (1) Depth-charge dischargers
- (2) Smoke floats (3) No. 1 store
- (4) Engineers' store
- (5) Petty officers' cabins
- (6) Depth-charge throwers
- (7) Carley float (8) Engine room
- (9) Depth charges (stowed)
- (10) Vents (11) Bofors gun
- (12) Shelter (13) Carley float

- (14) After boiler room
- (15, 15A) Side oil-fuel bunkers
- (16) Forward boiler room
- (17) Electricians' store
- (18) Officers' double cabin
- (19) Dinghy (20) Galley funnel
- (21) Crew's nest
- (22) Port 20-mm. gun (23) Bridge
- (24) Navigator's window

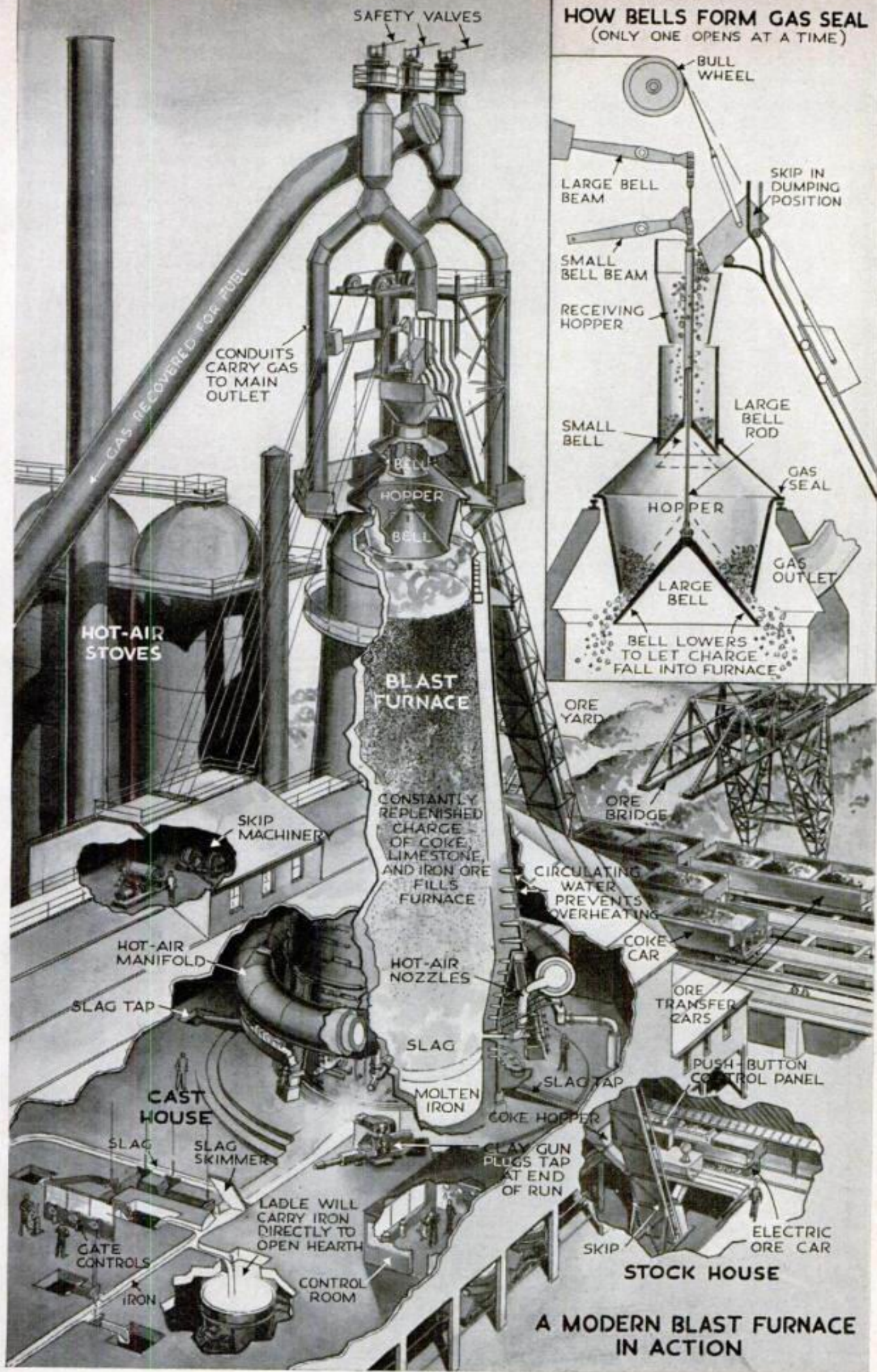
- (25) Direction-finding aerial
- (26) Wheelhouse and wireless cabin
- (27) Ship's bell (28) Loud hailer
- (29) Searchlight
- (30) Signaling light
- (31) Starboard 20-mm. gun
- (32) Lamp room (33) Dispensary
- (34) Officer's single cabin
- (35) Officer's single cabin

- (36) Oil-fuel bunker
- (37) Fresh-water tanks
- (38) Crew's accommodations
- (39) Crew's mess deck
- (40) Quick-firing four-inch gun

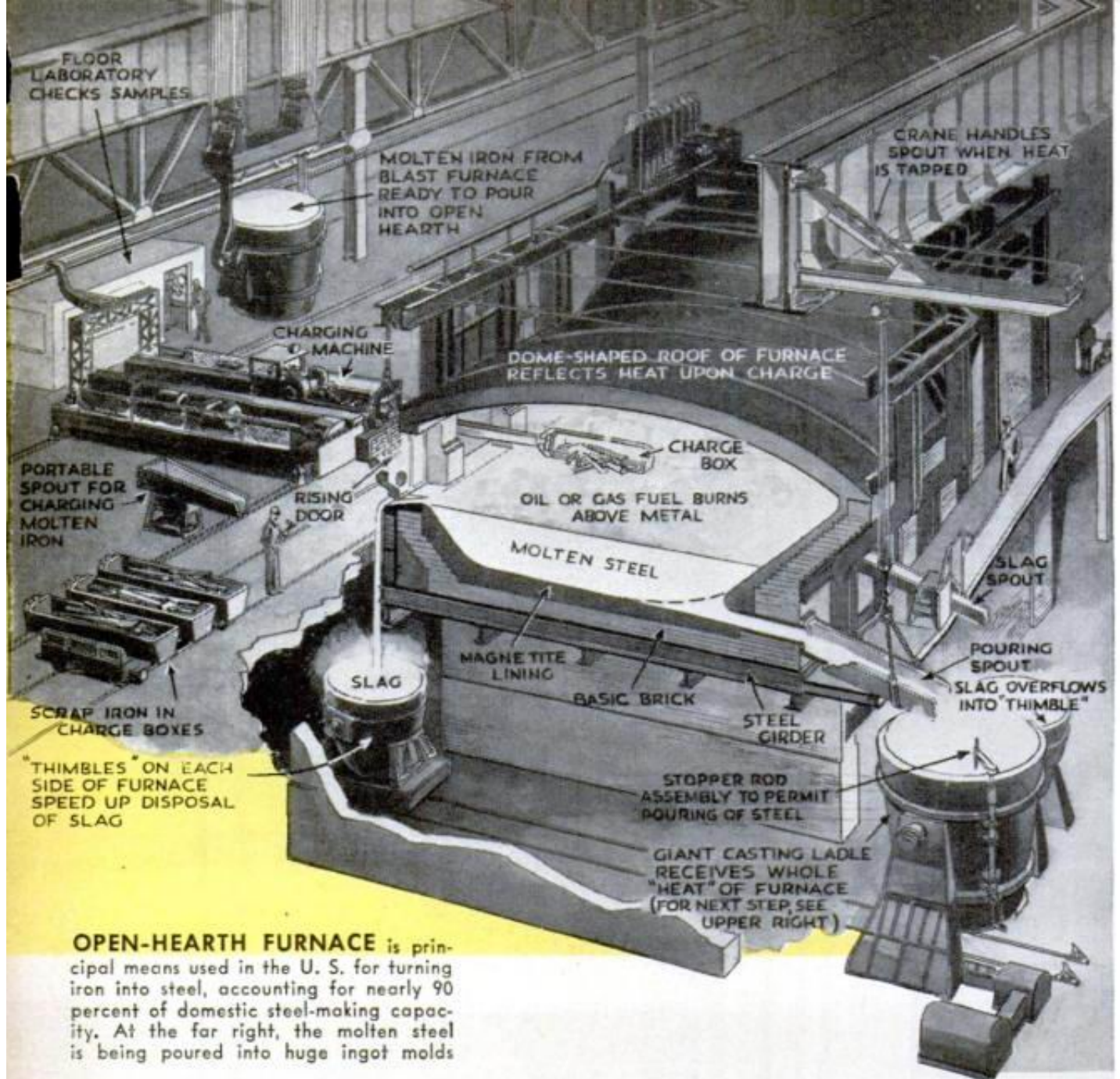
- (41) Windlass
- (42) Crew's accommodations
- (43) Gas-mask locker
- (44) Crew's accommodations
- (45) Fresh-water tank

Drawing by G. H. Davis from *The Illustrated London News*

G. H. DAVIS
1945



A MODERN BLAST FURNACE IN ACTION



OPEN-HEARTH FURNACE is principal means used in the U. S. for turning iron into steel, accounting for nearly 90 percent of domestic steel-making capacity. At the far right, the molten steel is being poured into huge ingot molds

trodes toward the charge with the aid of a small crane. When the electrodes barely touch the charge, electric arcs leap between them and the metal. The operator builds up the power to full voltage. Melting spreads from scattered puddles until the whole mass becomes liquid. Distribution of heat is believed to be aided by a curious electrical phenomenon, circulation of the metal in response to the heavy current passing through it.

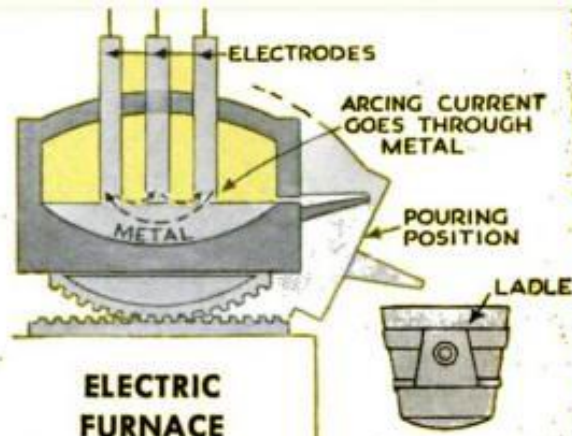
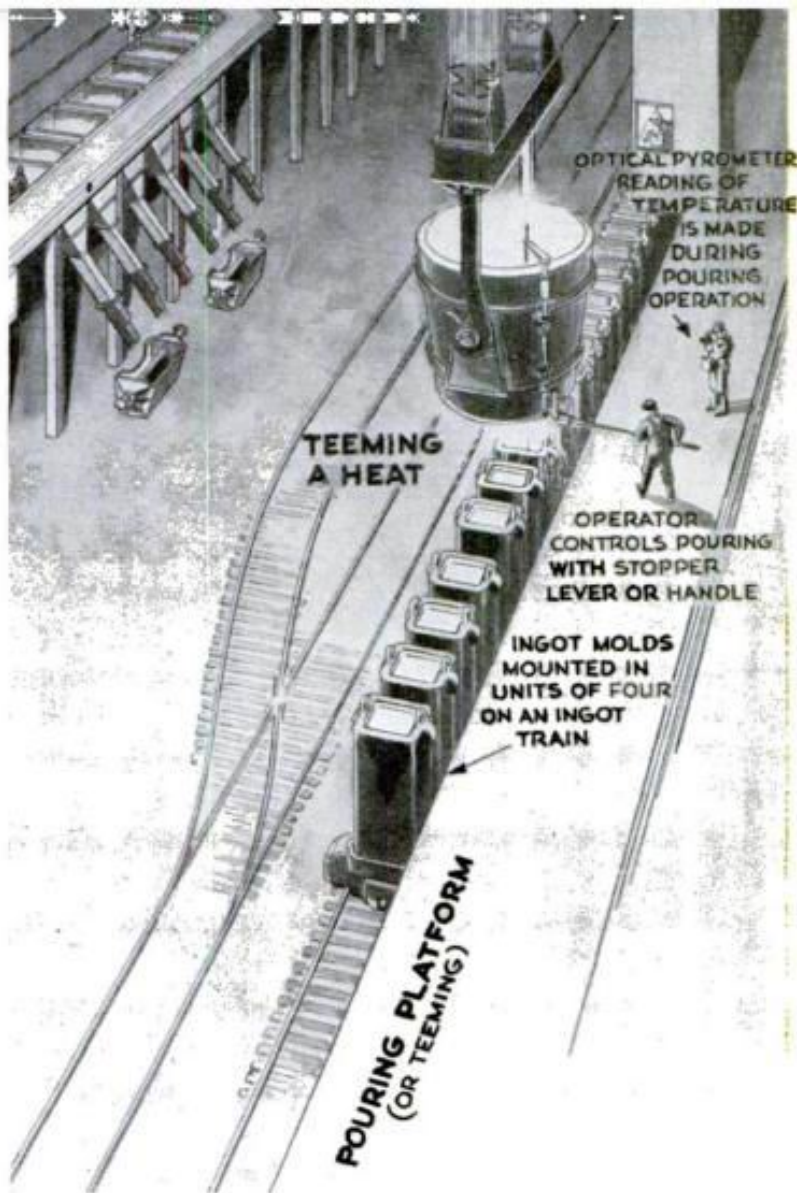
Frequent sampling calls for adding small amounts of various materials, until the composition is just right and the steel is ready to tap. Then, unseen machinery tilts the furnace and its whole surrounding platform. Metal pours from the tap hole into a waiting ladle, which transfers it to the ingot molds. A typical ingot of electric steel weighs seven tons.

Now the ingot, by whichever process produced, goes to a soaking pit. Here blast-

furnace gas reheats it to incandescence for passage through the many rolling mills that will reduce it to its final shape.

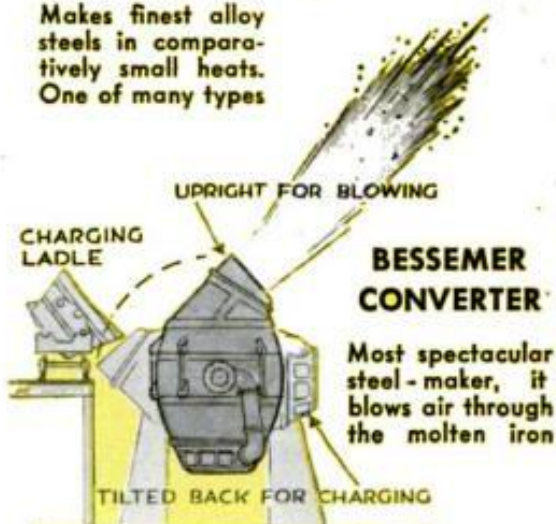
Two blasts from a signal horn. The slabbing mill is calling for metal. Over comes a glowing ingot to buck in vain against the mighty rolls—to be flattened between them and passed along, bumpety-bump, to other rolls that thin it again and again. Eventually it may end as coiled strip for manufacturing food cans. If the ingot's first stop was the blooming mill, it would take on a nearly square cross section, from being turned on its side between passages through the rolls. It might finally turn out as wire.

Where the home front is concerned, steel production is a major event on the war program. Industrial heads have been put together to scheme new ways for expanding the capacity of the steel mills, and it is possible that the output, at present 91,000,000



ELECTRIC FURNACE

Makes finest alloy steels in comparatively small heats. One of many types



BESSEMER CONVERTER

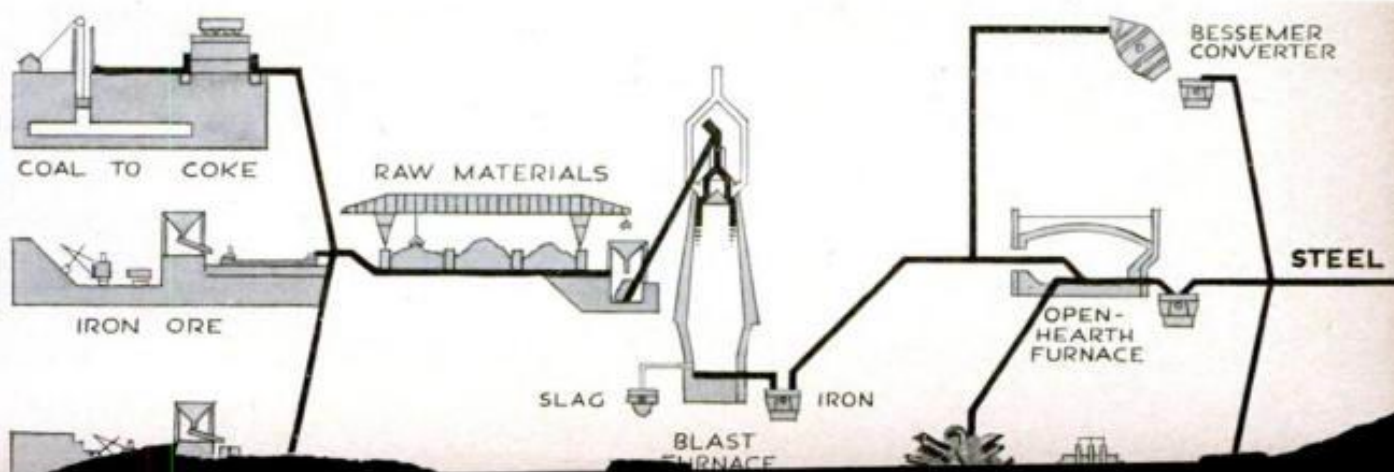
Most spectacular steel-maker, it blows air through the molten iron

tons a year, may in the next six months reach the staggering total of 96,000,000. Considering the daily requirements of steel tonnage, this goal is neither extravagant nor surprising. Every 24 hours the nation's war effort calls for enough steel to build and equip two giant battleships and more than 1,000 four-motor

bombers such as the Liberator and Fortress.

Four more signal blasts. "Faster!" There's a war to be won—and who knows it better than the men in the miles of steel plants that light up the Monongahela River by night? "Victory Valley," they call it, and with reason.

THESE ARE THE STEPS IN THE PRODUCTION OF STEEL





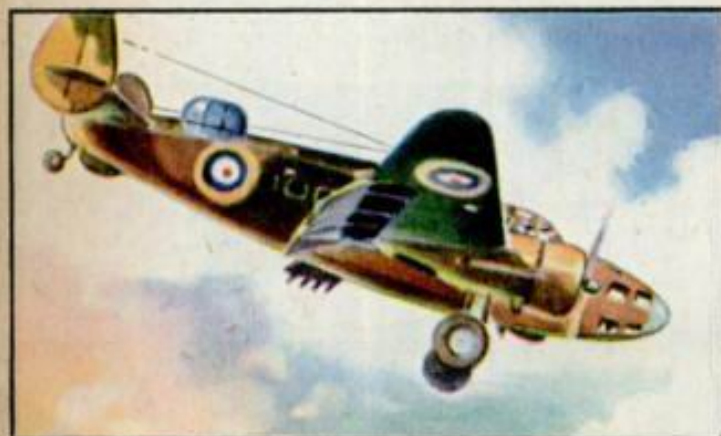
1927 First of the Vegas, with plywood monocoque fuselage. Wiley Post's "Winnie Mae" was a later Vega



1929 Sirius, designed by Lindbergh, was the first low-wing Lockheed. Orion and Altair types followed



1937 Howard Hughes' globe-girdling Model 14 had twin-engine, twin-tail design foreshadowing the P-38



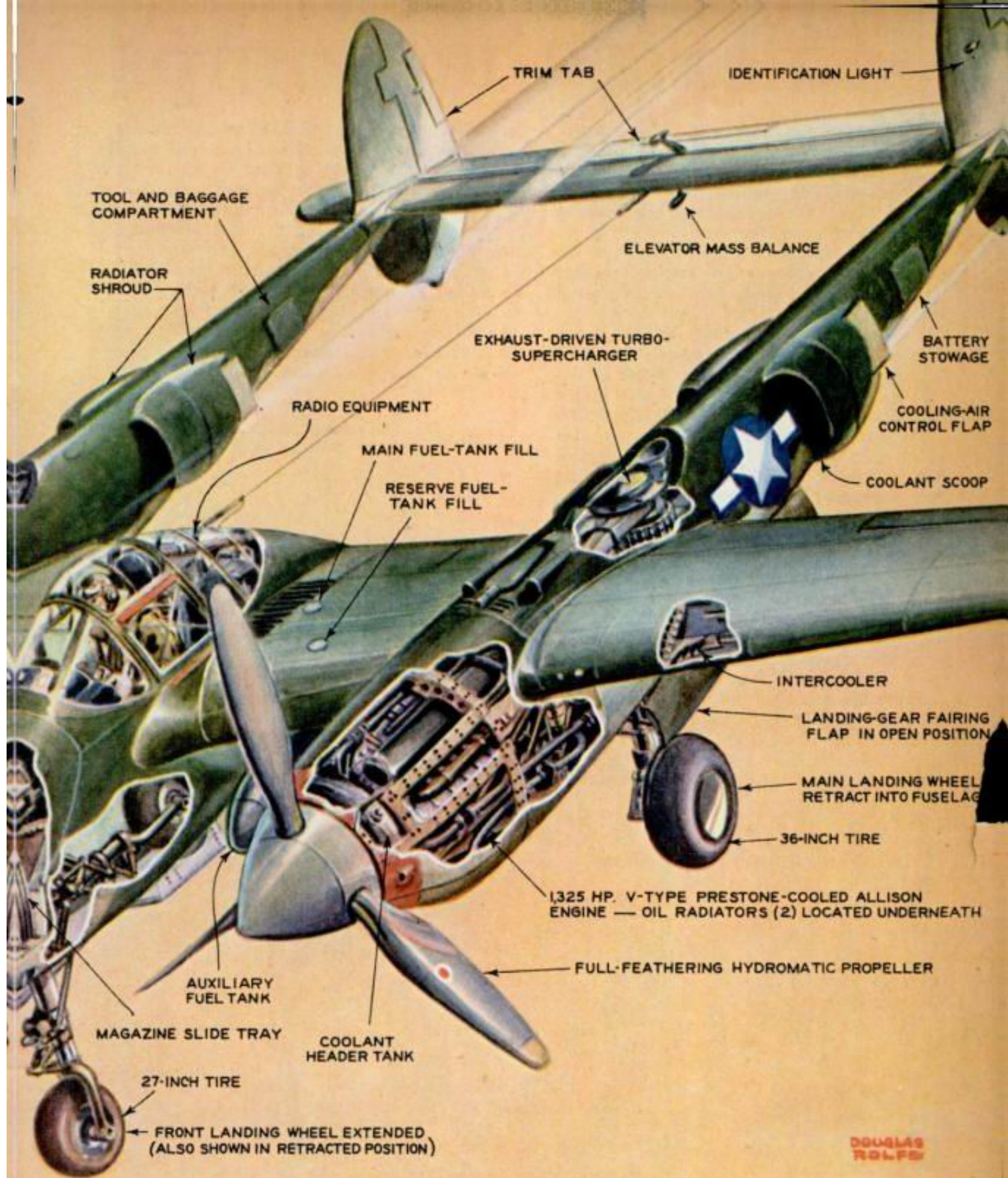
1939 Hudson bomber, military version of the 14, took Lockheed into warplane field. Ventura followed

Vega to Lightning..

Story of the P-38



BACK of the amazing and versatile performance of the P-38 Lockheed Lightning is a long line of famous planes. Although the first Lockheed (built by Allan and Malcolm Loughhead) appeared in 1912, the story really goes back only to 1927, when the first of the famous "star" series—the Vega—was born. With clean lines made possible by a patented plywood monocoque construction, the Vegas were among the fastest ships of their day. Wiley Post's



Winnie Mae was one of the early Vegas.

Then came the *Sirius*, *Orion*, and *Altair*, low-wing monoplanes that figured in the record-breaking ocean flights and are associated with such great names as Lindbergh, Earhart, and Kingsford-Smith. The *Orion* marked Lockheed's first use of retractable landing gear.

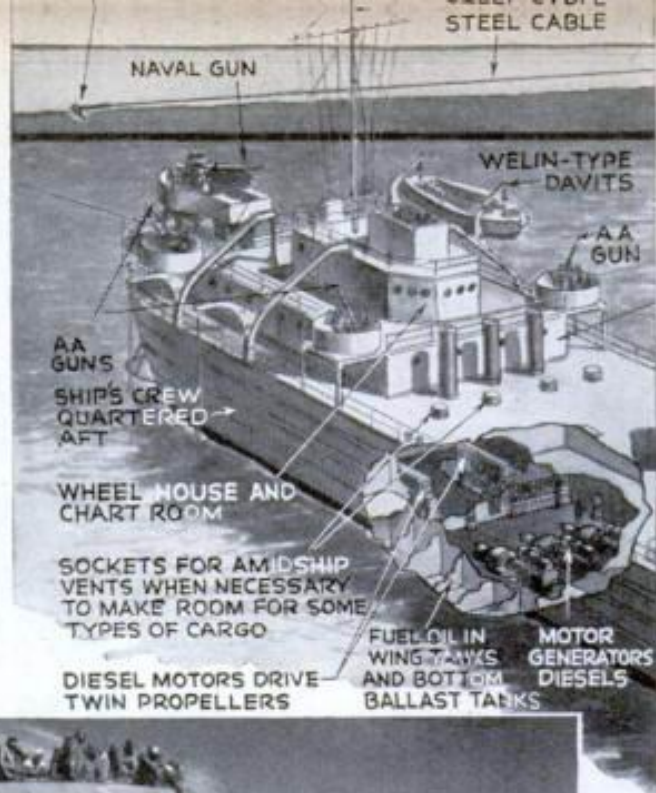
The Lightning's characteristic twin engines and twin-tail assembly first appeared in the *Electra*, in 1934. The twin tail was

perfected in the Lockheed 14, test-flown in 1937. This ship, also incorporating Lockheed-Fowler flaps and exceptionally high wing loading, made history in 1938 with Howard Hughes' 91-hour 'round-the-world flight.

Lockheed entered warplane construction by building modified 14's for the British as the Hudson bomber, followed by the *Ventura*. The P-38's prototype was test-flown secretly in 1939.



Grounded on the beach of a South Pacific island, a landing ship is connected with the shore by means of a mesh road that gives vehicles footing in sand



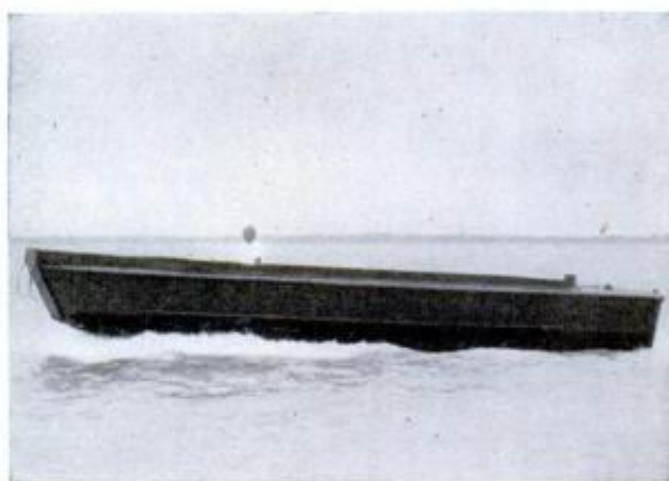
With ponderous bow doors open and ramp laid down, an LST discharges tanks in Africa. Traffic control gets vehicles out of the hold in orderly fashion



THESE ARE SOME OF THE LANDING CRAFT

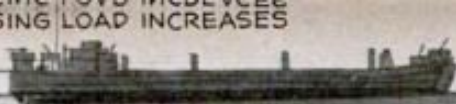
LCP(L). Landing Craft, Personnel (Large). This is the original spoon-bow Higgins landing boat. This model is no longer being built, but many are still in use in various theaters of war

LCPR. Landing Craft, Personnel, Ramp. Another early-type troop-landing boat. Like the LCP(L), it is still in service with U.S. amphibious troops, although construction of the model is discontinued



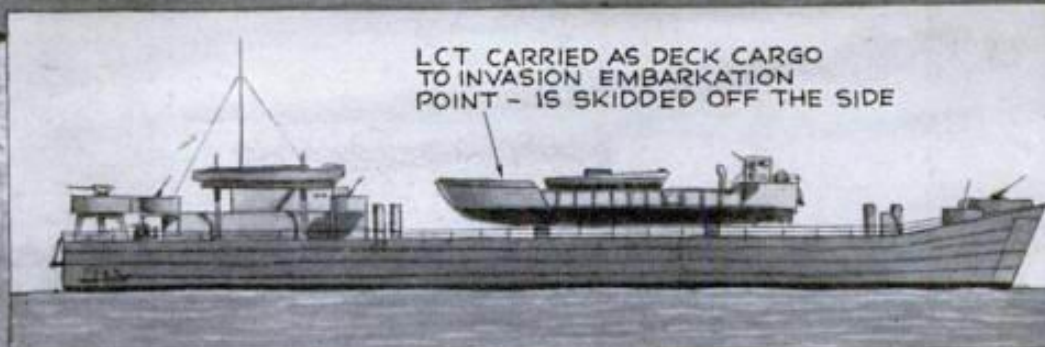
WHEN THE NEEDLE CLOSES
WHEN LST NEARS SHORE,
IT DROPS ANCHOR FROM
STERN AND PAYS OUT CABLE

AND TOWS IT OFF - LOSING LOAD INCREASES
BUOYANCY AND AIDS
IN OPERATION



OFFICERS' QUARTERS, MESS, AND GALLEY IN DECK HOUSE

LCT CARRIED AS DECK CARGO TO INVASION EMBARKATION POINT - IS SKIDDED OFF THE SIDE



LIFE RAFT

VENTS CARRY OFF EXHAUST GASES FROM TANK HOLD

BOOBY HATCH

TRAFFIC-CONTROL BOOTH

PREFABRICATED WELDED CONSTRUCTION

QUARTERS FOR COMBAT PERSONNEL

ELEVATOR HANDLES DECK CARGO

REMOVABLE STANCHIONS

RAMP WELL ABOVE WATER LINE PREVENTS FLOODING IN CASE OF LEAKS IN FRONT DOOR

RACK-AND-PINION DRIVE AGAINST GEARED QUADRANTS OPERATES DOORS

TANK HOLD

A.A. GUNS

OUTER DOOR

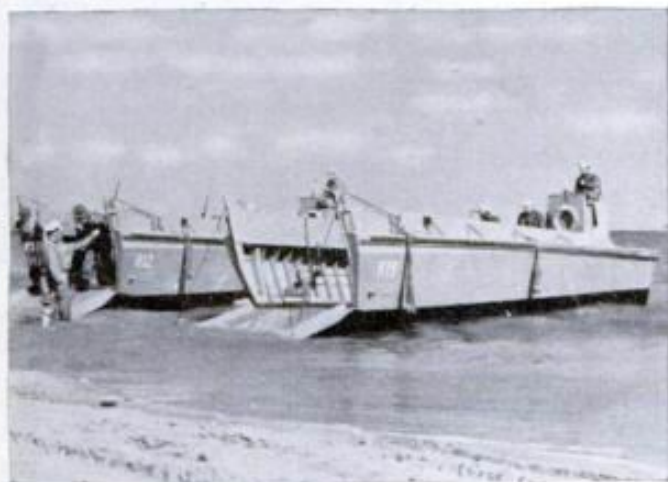
INNER DOOR ACTS AS RAMP

LST, OCEAN-CROSSING TANK CARRIER

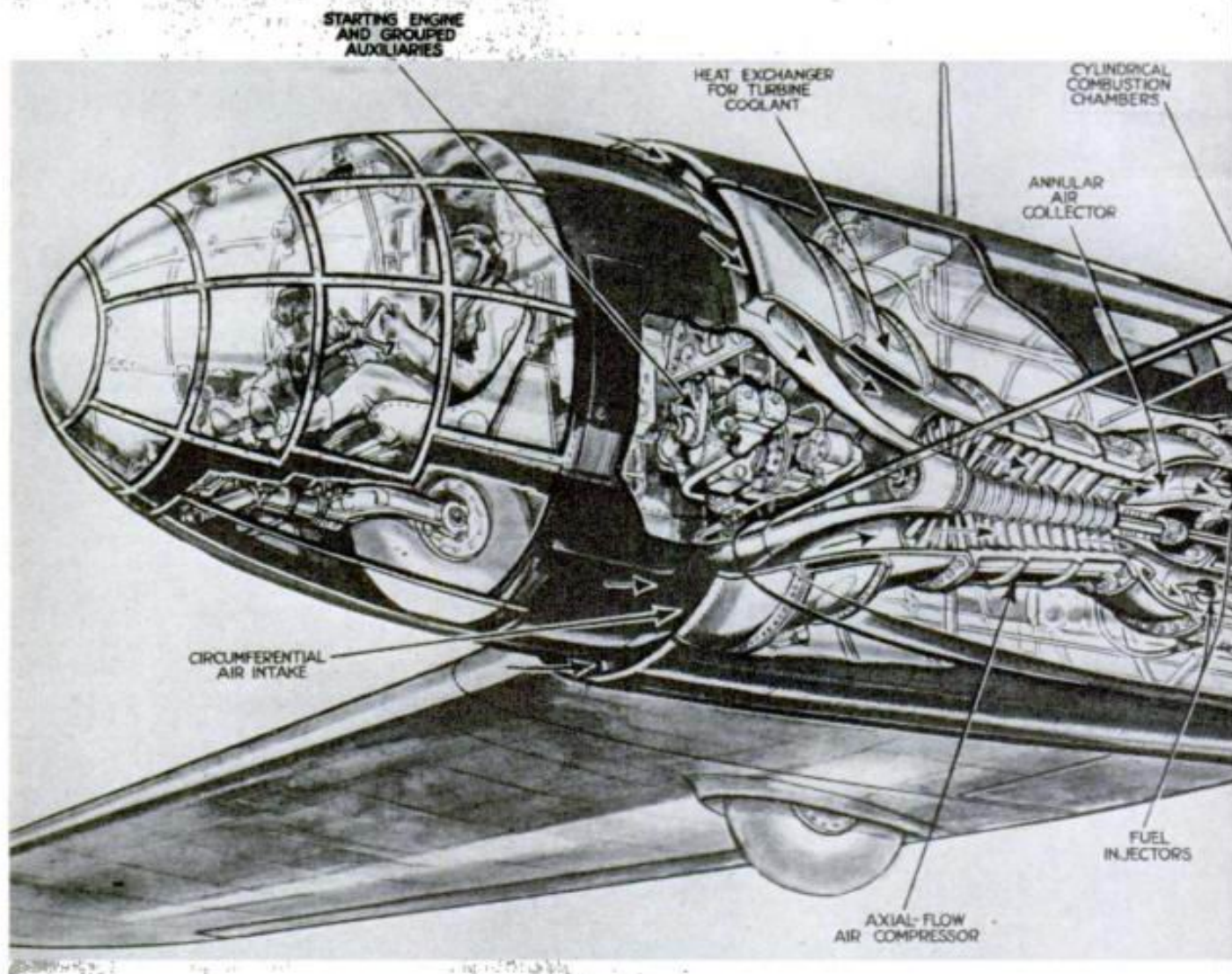
NOW BEING USED BY AMERICAN FORCES

LCV. Landing Craft, Vehicle. Capable of carrying a jeep or a light tank along with personnel, this type was evolved by putting a ramp bow on the original Higgins boat, with a broader beam

LCVP. Landing Craft, Vehicle, Personnel. The Navy's standard "beach climber" is 36 feet long, Diesel powered, manned by four men. Can carry a jeep and crew, howitzer and crew, or 36 men



HOW WILL JET PROPULSION AFFECT AIRCRAFT DESIGN? HERE IS A BRITISH ARTIST'S IDEA



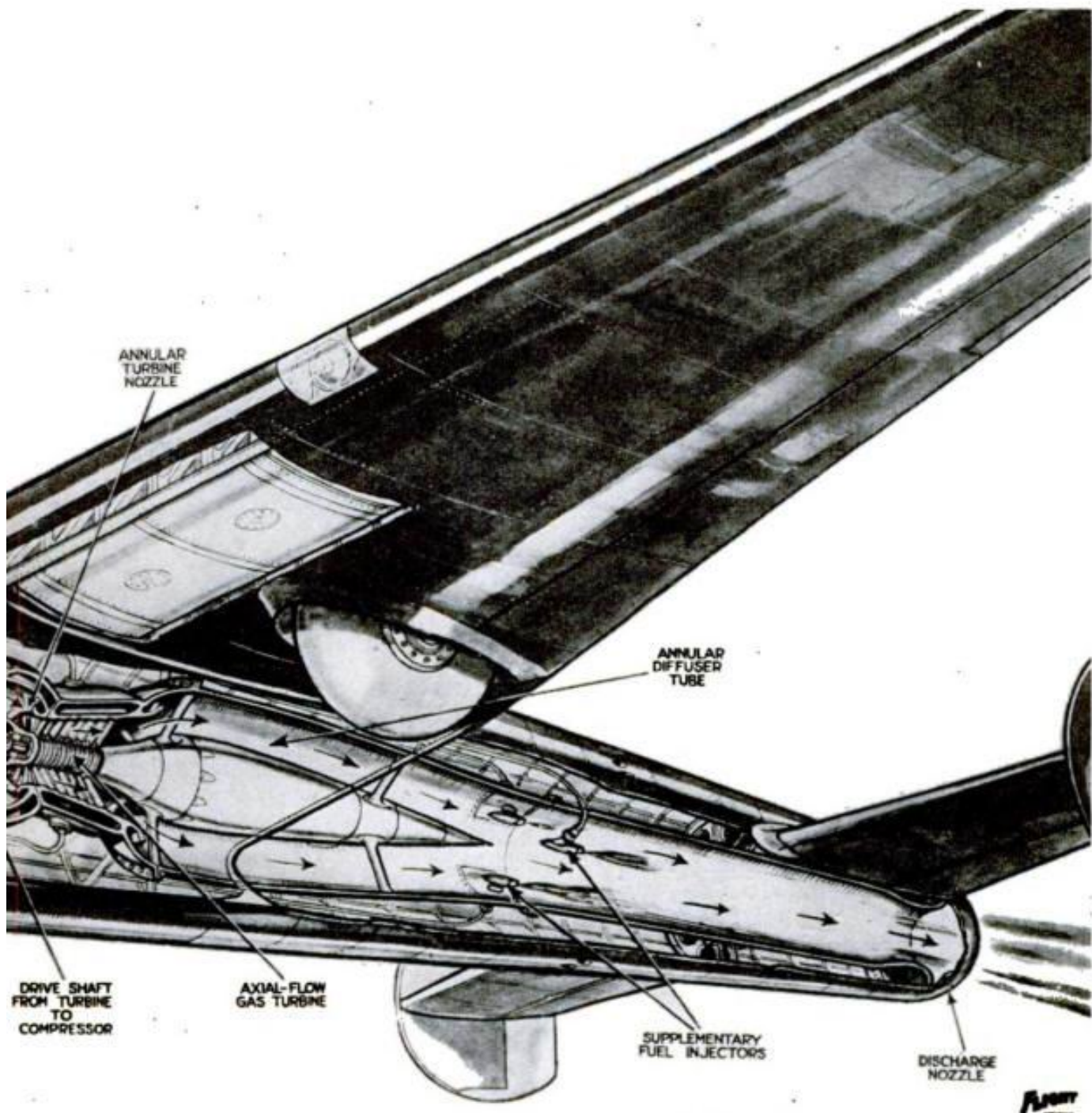
Propellerless Power for Planes

JET propulsion, thrown into the limelight by the simultaneous announcement of British and American warplanes using this new type of power plant (P.S.M., April '44, p. 85), has been hailed in some quarters as one of the greatest advances in the history of aviation. Certainly it promises new speed and power for aircraft in certain categories.

Apart from the advantages or disadvantages of the jet engine as a source of power, some interesting questions are raised by its

application to the conventional features of aircraft design. How will it adapt itself to the familiar lines of propeller-driven planes? Builders will be confronted with an entirely new set of conditions in the apportionment of space and the planning of auxiliary equipment to make an efficient fighting or working ship.

A tentative answer to some of these problems is seen in the drawing above. Made by M. A. Miller for the magazine *Flight*, it gives the British artist's conception of an



Presents New Problems to Builders

idealized jet-propelled plane combining various features common to this type of craft.

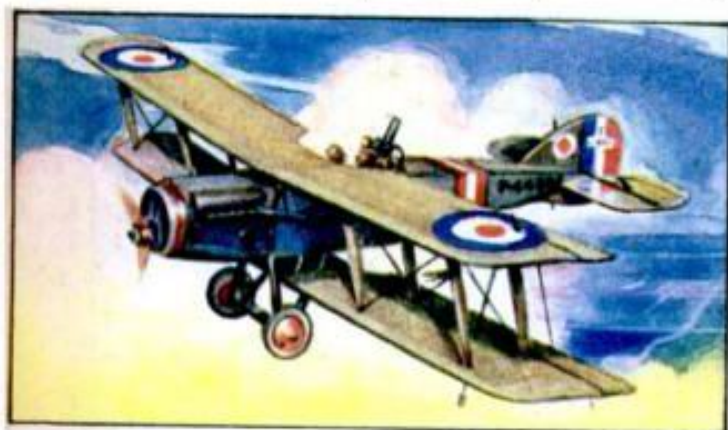
A notable change is the low landing gear, with main wheels partly submerged and nose wheel retracted. Having no propeller, the jet plane is freed from the limitation imposed on conventional planes, which must stand high enough on the ground that their blade tips will clear by at least nine inches under all conditions. In warplanes, the absence of the propeller and engine cowling also permits better visibility from the cock-

pit and greater freedom in the mounting of forward guns.

In this conception, a single jet engine occupies the main fuselage of the plane, air being picked up from around the nose by a circumferential scoop. According to press reports, the actual British jet plane has two engines mounted in twin fuselages and has been mistaken for the American P-38. An auxiliary engine is used in starting, to turn the air compressor. In operation, this is done by the turbine.



In 1912, Barnwell's 35-hp. Scout, with a speed of only 90 m.p.h., set the pattern for modern plane efficiency



Five years later his two-seater Brisfit was outfighting the fastest German single-seater planes of World War I



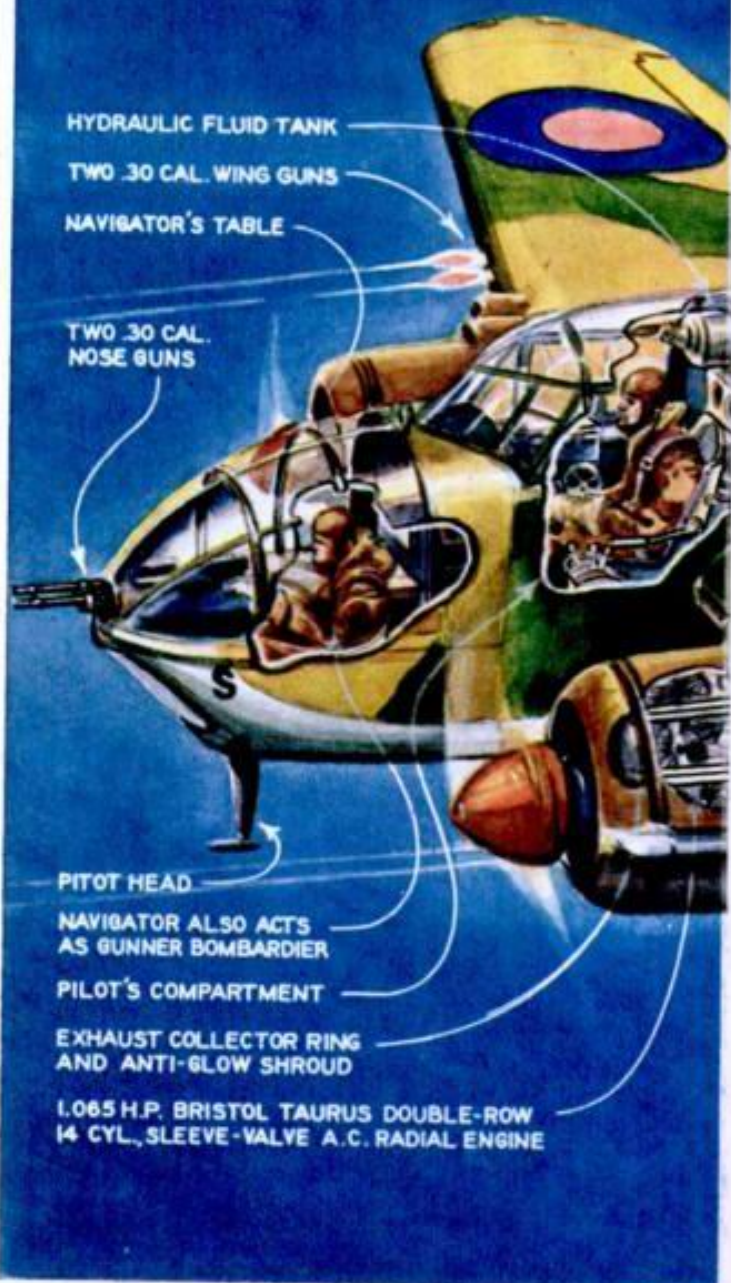
A midwing monoplane with retractable landing gear was conceived by the designer as far back as 20 years ago



The Bristol Bulldog, of which Barnwell was a codesigner, became the RAF's standard single-seater fighter in 1930

WHY THE NAZIS

Britain's Bristol Beaufort Torpedo Plane



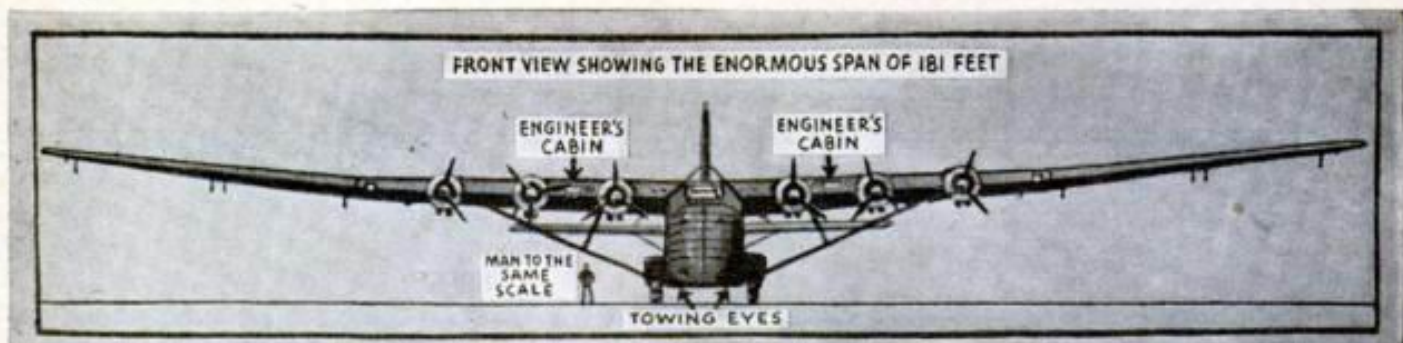
SHORTLY after it was organized in 1910, the Bristol Aeroplane Company engaged as its head designer the late Captain Frank Barnwell who, for the next 25 years, was the mainspring of a company that has turned out some of the finest fighting planes Britain has ever put into the sky. Barnwell's very first design—a tiny 35-hp. plane that compares favorably with modern planes of similar power—completely revolu-

SHUN THE SEA

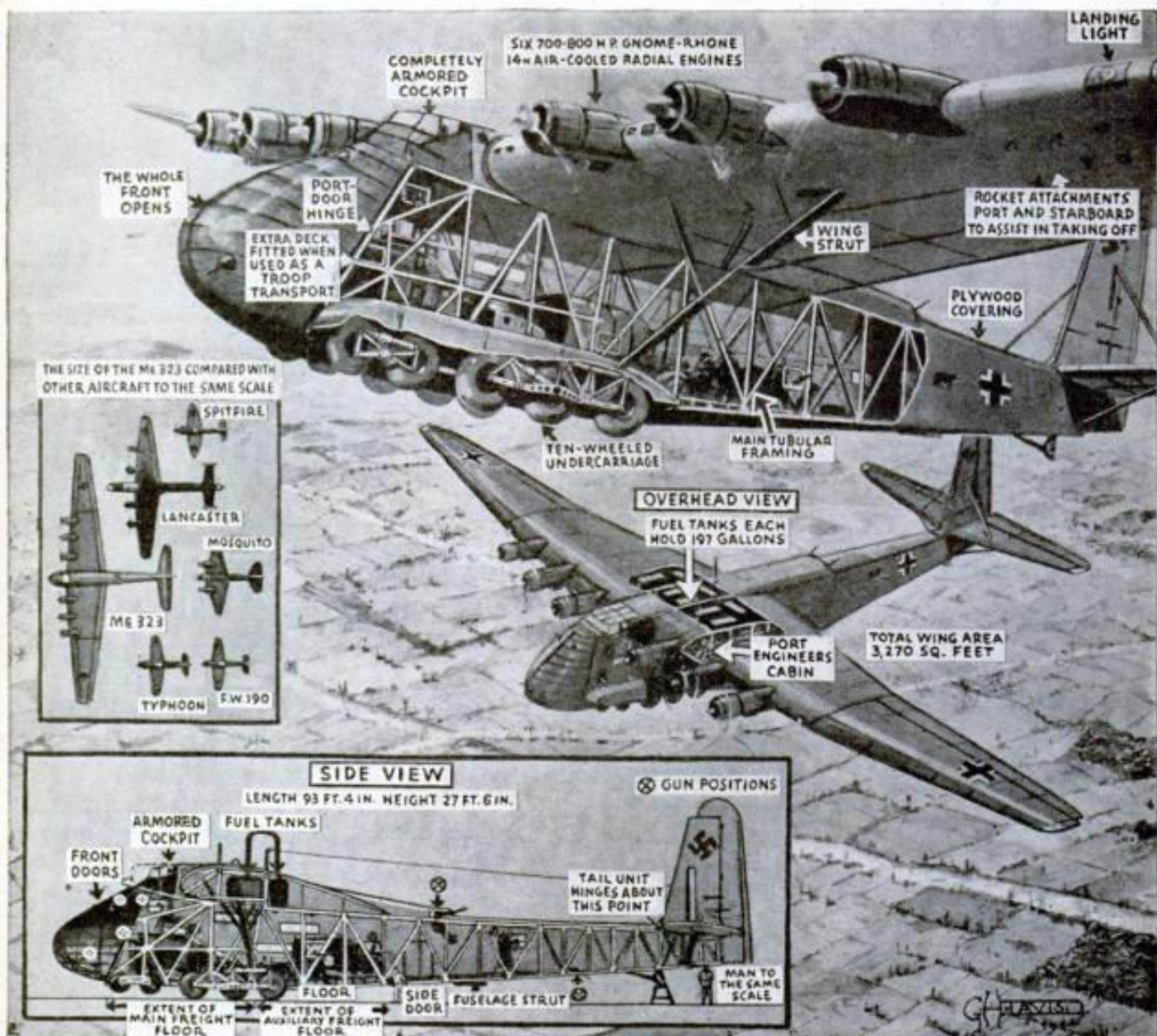


tionized the concept of airplane efficiency of that day. In 1917 he designed the Brisfit, a fast and highly maneuverable two-seater that is said to have been the best fighter in World War I and set an all-time record by remaining in the service of the RAF for nearly 10 years after the close of hostilities. In 1922, Barnwell brought out a plane that was 20 years ahead of its time—an experimental midwing monoplane with a completely encowled radial engine and retract-

able landing gear. Thirteen years later he produced the Blenheim, the fastest two-engined bomber in the RAF and the prototype for two other now famous ships: the Beaufort, Britain's standard land-based torpedo plane, and the Beaufighter, which, with its four cannon and six machine guns, is the world's most heavily armed fighter. Both planes have top speeds of over 300 m.p.h. The Beaufort is being used in large numbers by Britain's Coastal Command.



Secrets of Germany's Flying Freighter



TOW PLANE AND ROCKETS LAUNCH ME-323 POWERED GLIDER

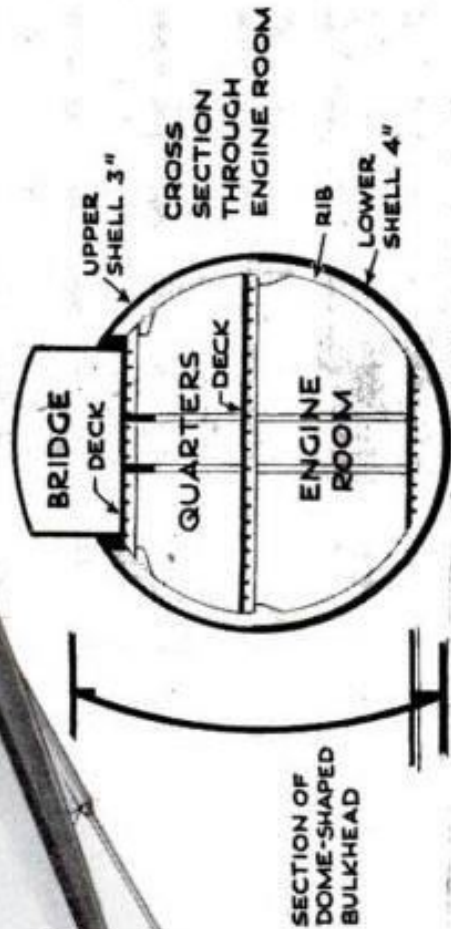
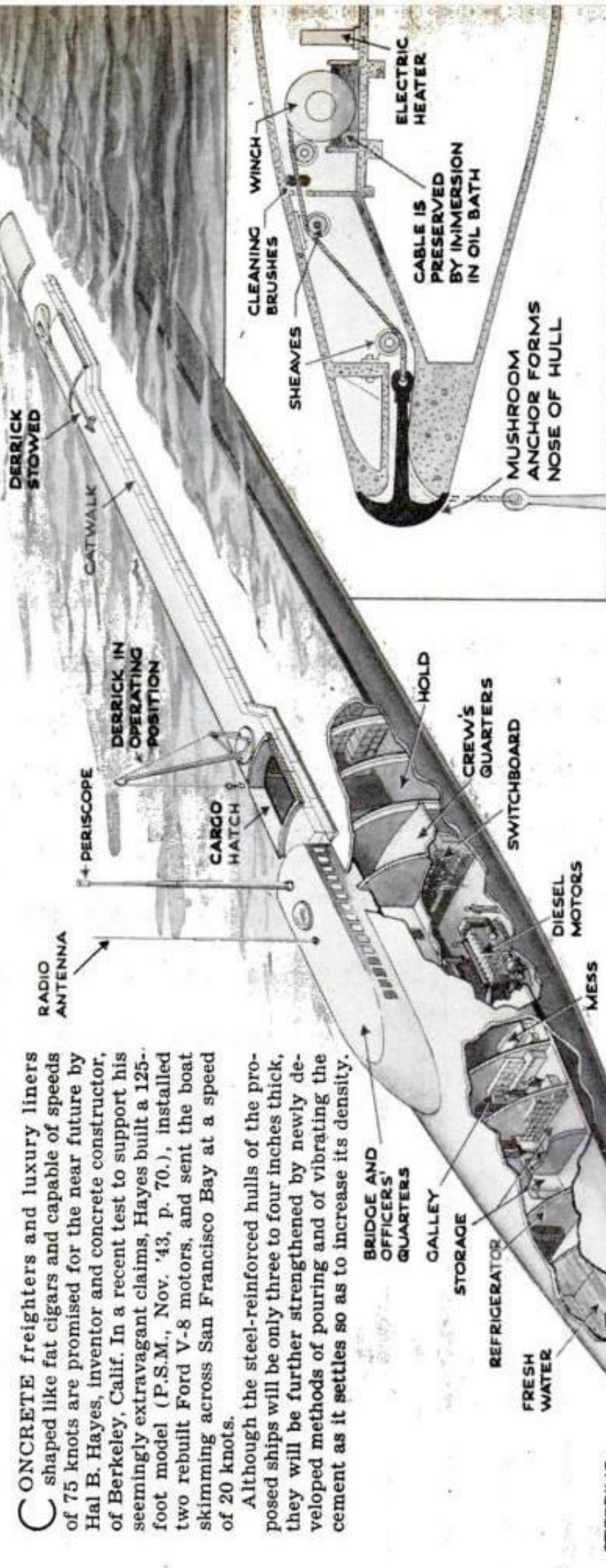
How the German ME-323 air transport carries its fabulous loads of men and equipment is shown in these drawings by G. H. Davis from *The Illustrated London News*. Rated as a powered glider, the six-engined

craft requires an assisted take-off; a tow plane and eight wing-mounted rockets help lift it off the ground. For loading and unloading, huge doors in the nose are opened as shown in a photo on page 128.

INVENTOR NOW PROMISES 75 KNOTS FOR CONCRETE LINERS

CONCRETE freighters and luxury liners shaped like fat cigars and capable of speeds of 75 knots are promised for the near future by Hal B. Hayes, inventor and concrete constructor, of Berkeley, Calif. In a recent test to support his seemingly extravagant claims, Hayes built a 125-foot model (P.S.M., Nov. '43, p. 70.), installed two rebuilt Ford V-8 motors, and sent the boat skimming across San Francisco Bay at a speed of 20 knots.

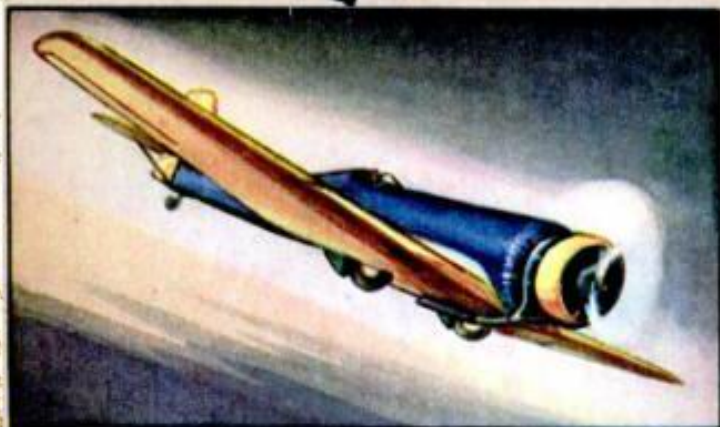
Although the steel-reinforced hulls of the proposed ships will be only three to four inches thick, they will be further strengthened by newly developed methods of pouring and of vibrating the cement as it settles so as to increase its density.



Powered by either steam or Diesel engines, the boats will lie low in the water—with a load water line of 22 feet. Yet, because of their streamlining, they will incur 27 percent less water friction than ships of conventional design. By means of simplified inner construction, the boats will be able to carry about 30 percent more cargo than Liberty freighters of equal size.

According to the designer, the ships will require only one-tenth the amount of metal that goes into an all-steel boat, and one can be built in approximately 11 days by construction crews consisting mainly of unskilled workmen.

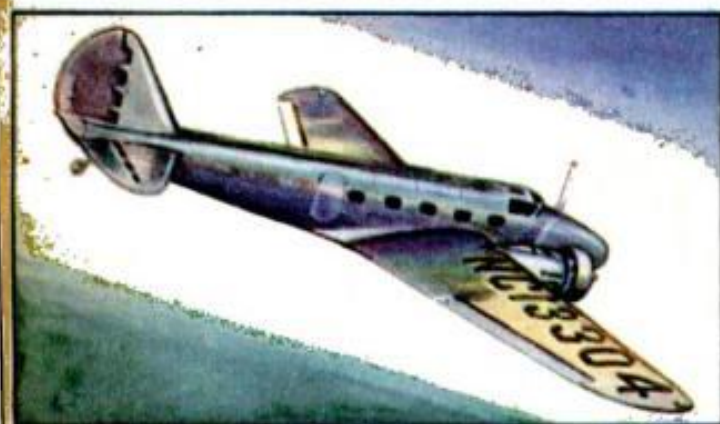
WHAT MAKES THE FLYING FORTRESS SO TOUGH?



The Monomail of 1930, earliest of the Fort's ancestors, bequeathed retractable landing gear and all-metal skin



The B-9, which shamed the biplane fighters of 1931 with its speed, contributed largely to the Fort's swiftness



From Boeing's commercial transports, many of which are still flying after 11 years, came a family ruggedness

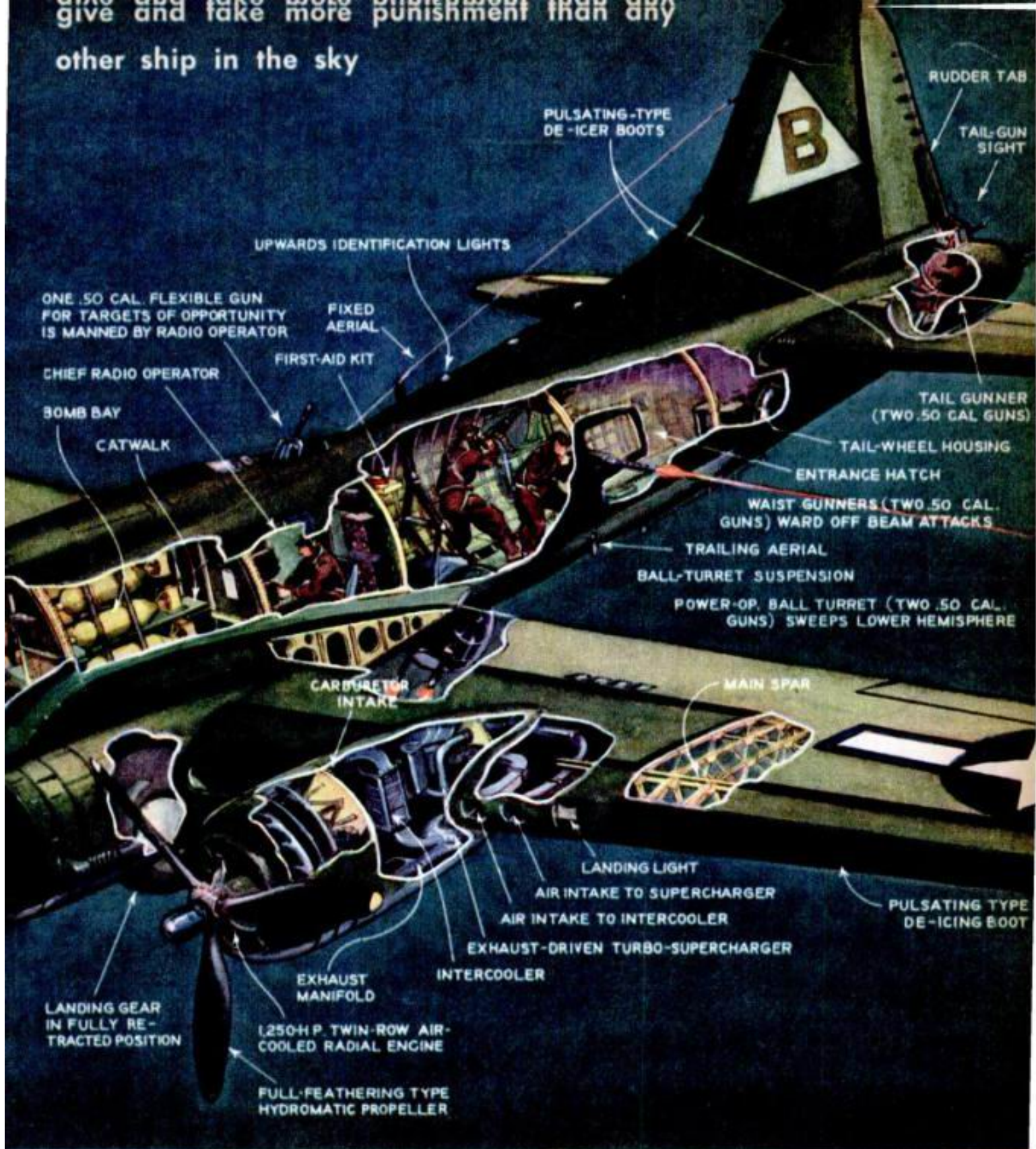


From its dad, the B-15, the Fort got four engines and many of its structural and operational characteristics



WHEN a Fortress flies home from a raid so riddled that daylight shines through at every angle, it isn't a magic charm that holds it together. It's a heritage it has received from a distinguished line of ancestors reaching all the way back to the Boeing Monomail of 1930. From this ship the Fort gets its countersunk rivets, retractable landing gear and the smooth, rigid-stressed skin that enables a

give and take more punishment than any other ship in the sky

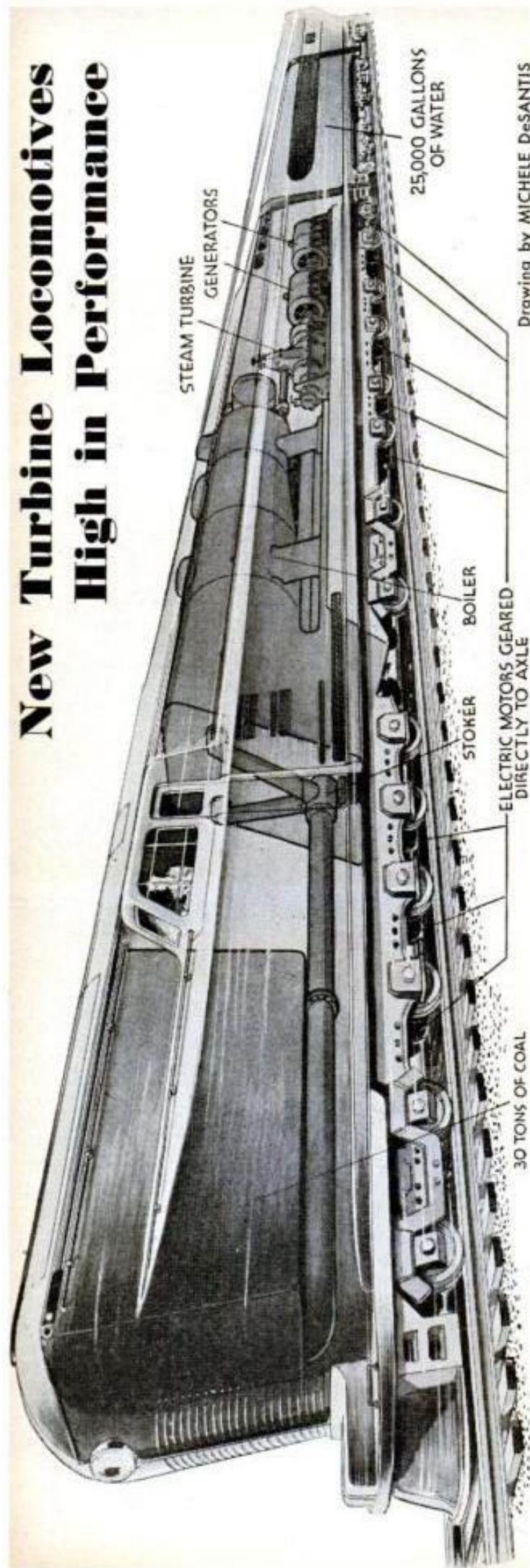


plane's outer shell to carry a large part of the bearing load. Its high speeds have been inherited from the B-9, or Boeing Death Angel, which shamed the biplane fighters of 1931 out of the sky with its pursuit-speed performance. From the commercial Boeing 247's, many of which are still going after 11 years of service, it received a family tradition of longevity. And from the B-15 it has inherited its four engines.

Another secret of the ship's stamina is

the decentralization of stress. The fuselage, for instance, has 74 transverse members, varying in weight from tiny circumferentials to big, main bulkheads. Across these are riveted reinforcing stringers, and over all is a riveted skin of aluminum. The same is true of the wings, fin, and stabilizer. It is this type of construction that makes it possible for one part of the ship to be blown to smithereens while an adjacent part remains intact.

New Turbine Locomotives High in Performance



Drawing by MICHELE DeSANTIS

WHIRLING turbine blades, instead of flashing pistons, will drive powerful streamline locomotives to drag the crack steam-powered trains of tomorrow. Two leaders of this new trend in American railroading are shown on this page.

Most revolutionary is the turbo-electric engine above, designed for the Chesapeake and Ohio Railway. Steam from its coal-fired boiler will operate the turbine to deliver 6,000 horsepower to a pair of generators. These will feed 4,000 kilowatts of electricity to the motors that spin the driving wheels for speeds above 100 miles an hour under full load.

Coal is carried in the head end, while the tender is given over entirely to water. Over-all length, including the tender, is

more than 137 feet; height is 15½ feet. Three of the giants will be built for the C. & O. by the Baldwin Locomotive Works, with Westinghouse furnishing the electrical equipment. These will be the first steam turbo-electric locomotives to hit the rails in the U. S.

Similar in arrangement, except that the turbine will be geared directly to the driving wheels, is the "Triplex" (below), designed for the Pennsylvania Railroad. Swiveling trucks will enable it to take any curve that a standard passenger coach can negotiate.



leave Big Problems Unsolved

through the air, increases rapidly around landing speeds.

Perhaps the development of some super-light-and-strong metal may make it possible to construct variable area wings that weigh no more than present supporting surfaces. In the engines that powered some Schneider Cup racers, the pistons and some other parts were made of magnesium. This metal is light and hard. Its defect is that it corrodes easily. Sea water eats into it as acid eats into tin. However, a new noncorrosive magnesium

alloy, called MG7, has just been announced in Germany for aircraft use. The metal that appears at present to be the best combination of lightness and strength is beryllium, a laboratory product literally worth its weight in gold. Some aircraft engineers calculate that when the price of this rare "gray gold" drops to \$50 a pound, it will pay to use a beryllium alloy in the framework of planes.

II. Free-Wheeling Propellers

ANOTHER badly needed innovation is "free wheeling" for propellers. When an engine cuts out in the air, the wind keeps the propeller whirling against the drag of the balky engine. This slows up the blades, adding tremendously to their resistance in passing through the air.

Thus, when one wing-engine stops on a tri-motored ship, the other two motors not only have to keep the plane in the air but also have to drag along the revolving blades that turn over the dead power plant. Some sort of simple "free-wheeling" device in the transmission line that would allow

the pilot to disengage the propeller from the engine and let it spin free, if the motor quits, would be an improvement welcomed by airmen. This innovation must be light, adding little weight to the plane; simple, reducing the danger of its getting out of order; and, also, strong enough to transmit the power.

III. An Anchor for Seaplanes

WHEN the DO-X flew across the Atlantic and then cruised up along the coast of South and North America to New York City, it carried at the nose of its huge flying boat hull a big metal anchor resembling those on ocean liners. The bigger the seaplane, the larger and the heavier the anchor required to hold it when it is floating at rest on the water. In flight, this heavy mooring iron must be taken along, eating up power and cutting down the load the plane can carry. In the "wanted" column of inventions is a new kind of anchor for flying boats and seaplanes that does not depend so much upon weight for its holding power.

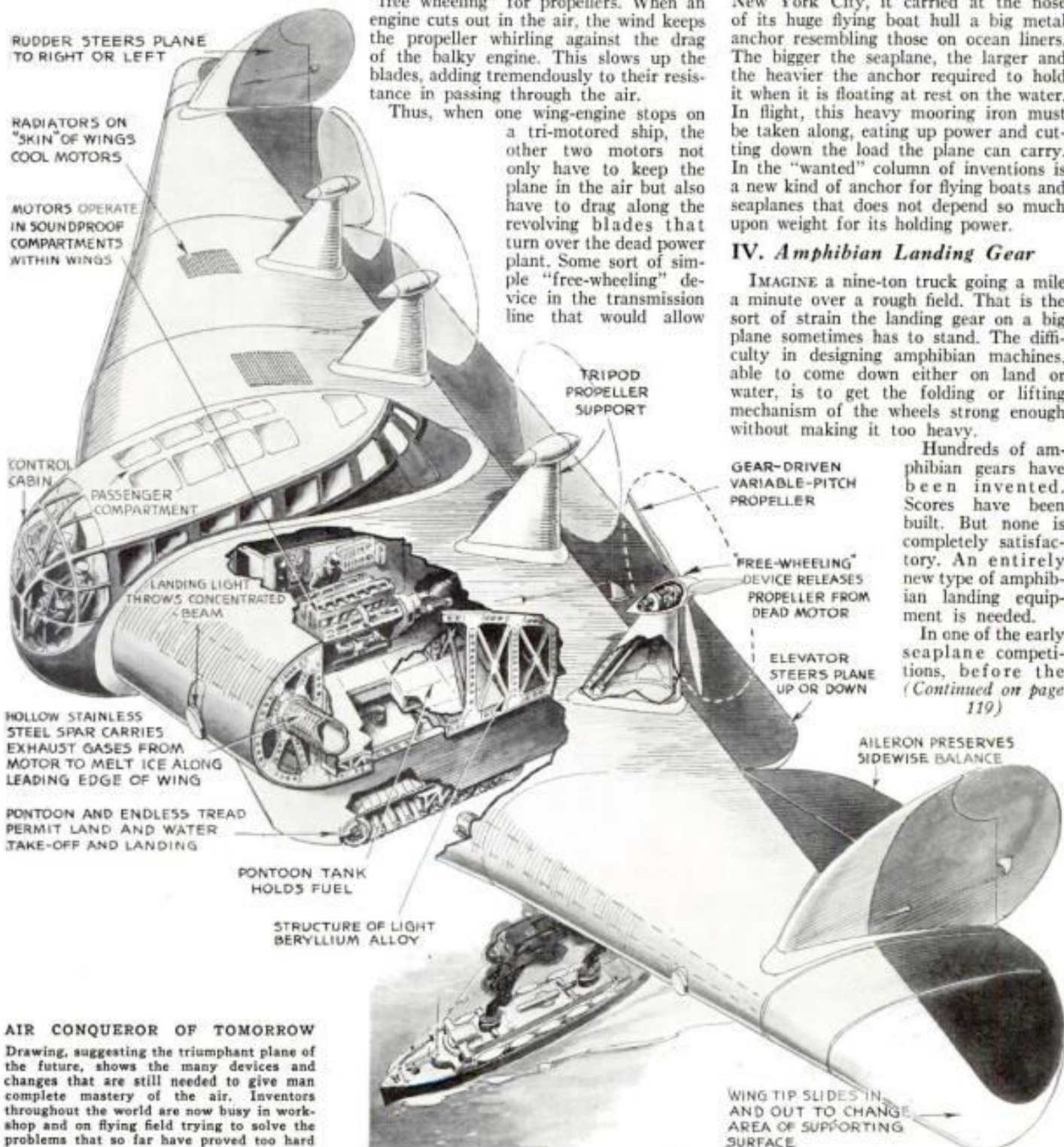
IV. Amphibian Landing Gear

IMAGINE a nine-ton truck going a mile a minute over a rough field. That is the sort of strain the landing gear on a big plane sometimes has to stand. The difficulty in designing amphibian machines, able to come down either on land or water, is to get the folding or lifting mechanism of the wheels strong enough without making it too heavy.

Hundreds of amphibian gears have been invented. Scores have been built. But none is completely satisfactory. An entirely new type of amphibian landing equipment is needed.

In one of the early seaplane competitions, before the

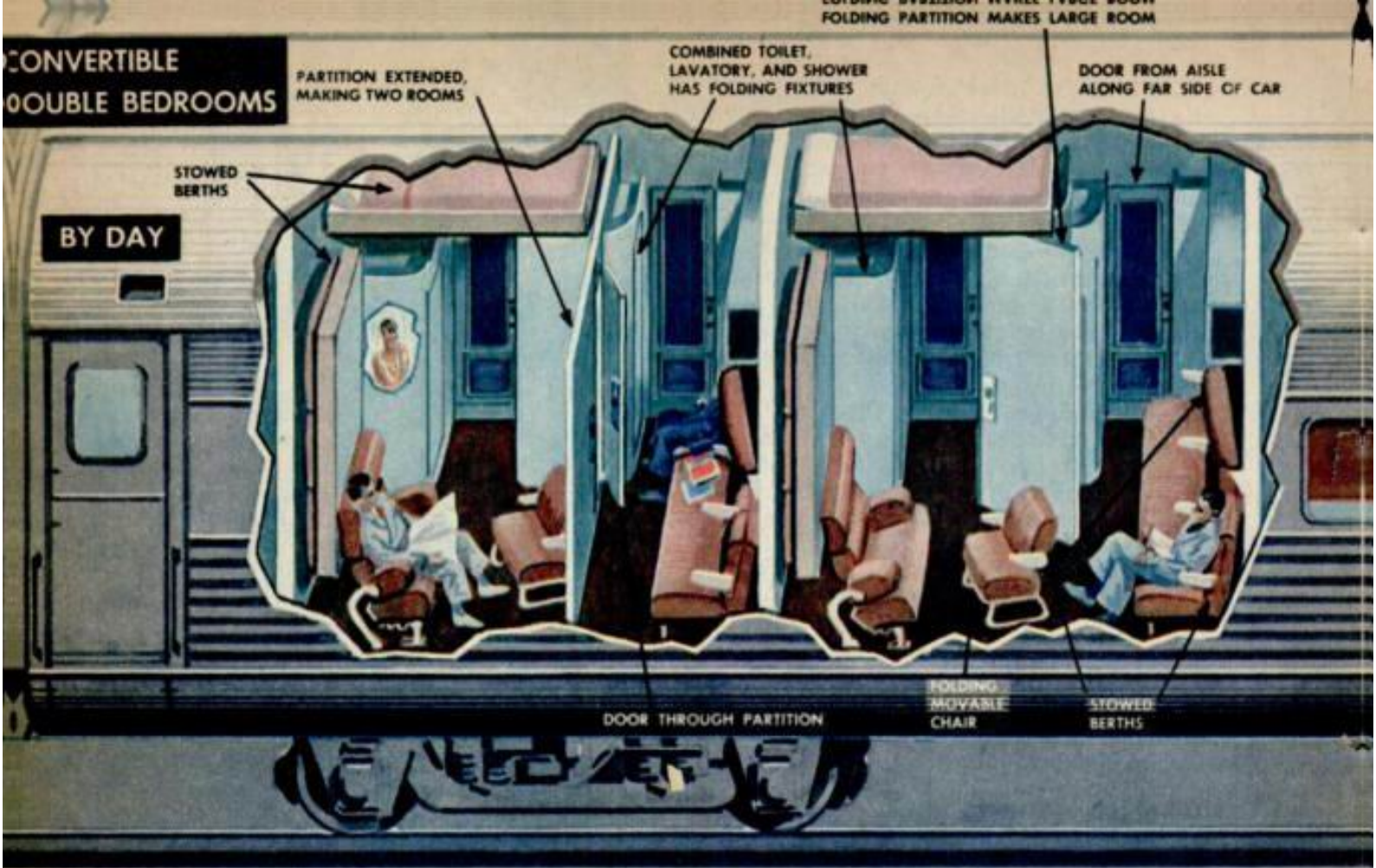
(Continued on page 119)



AIR CONQUEROR OF TOMORROW

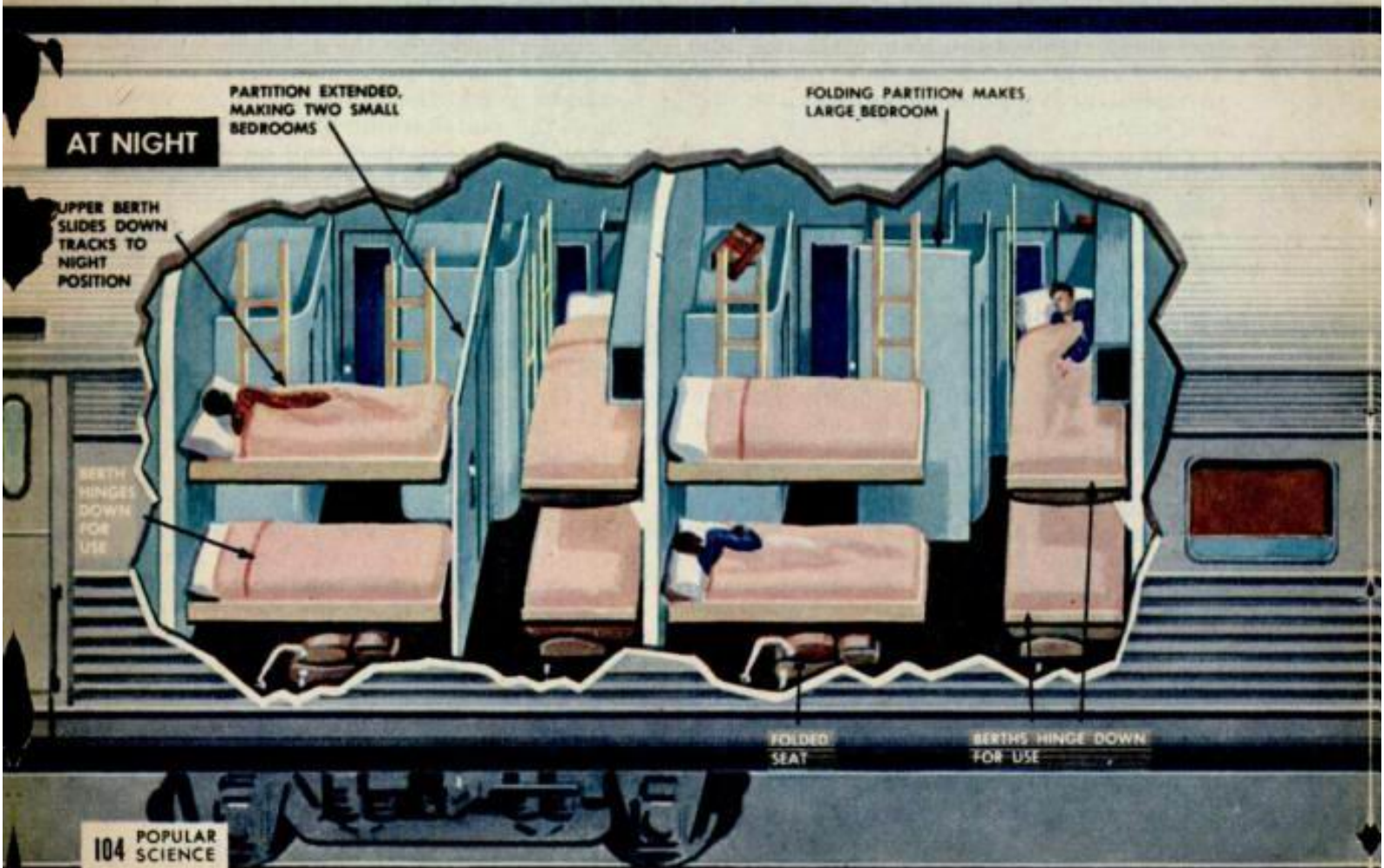
Drawing, suggesting the triumphant plane of the future, shows the many devices and changes that are still needed to give man complete mastery of the air. Inventors throughout the world are now busy in workshop and on flying field trying to solve the problems that so far have proved too hard

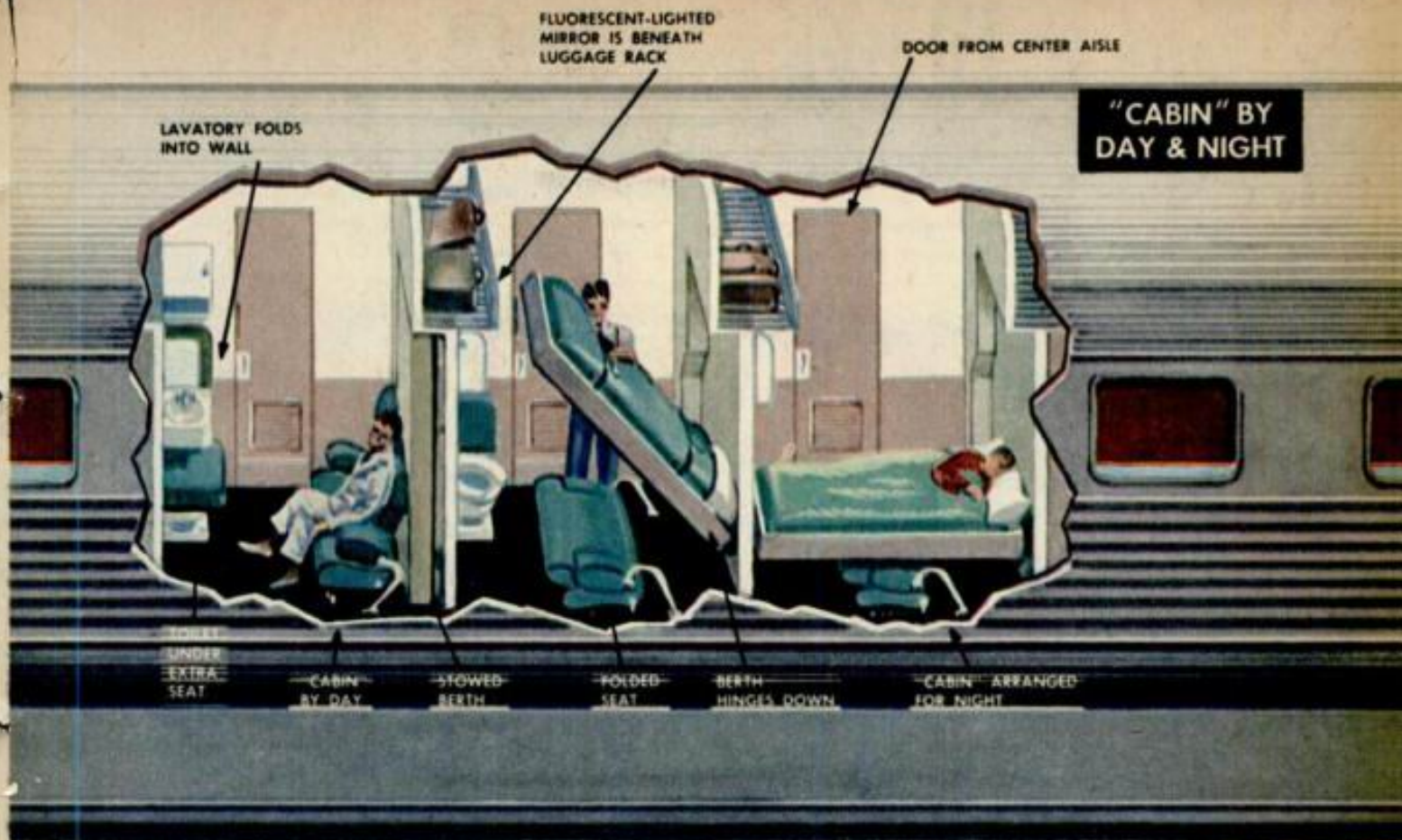
CONVERTIBLE DOUBLE BEDROOMS



Railroads found that fore-and-aft and crosswise berths are about equally popular. Cutaways show

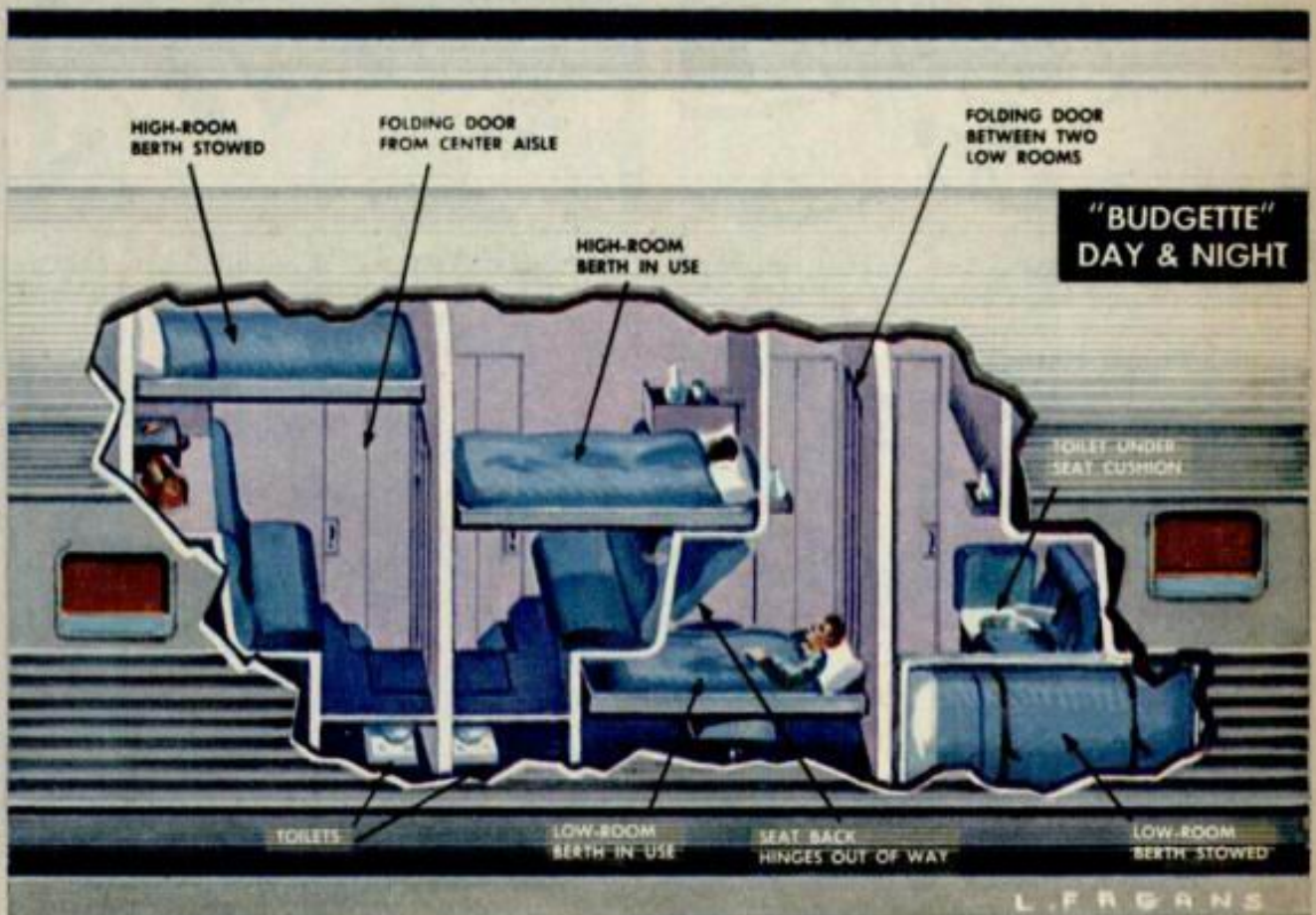
how double bedrooms alternate between the two types, or provide both in a master drawing room.



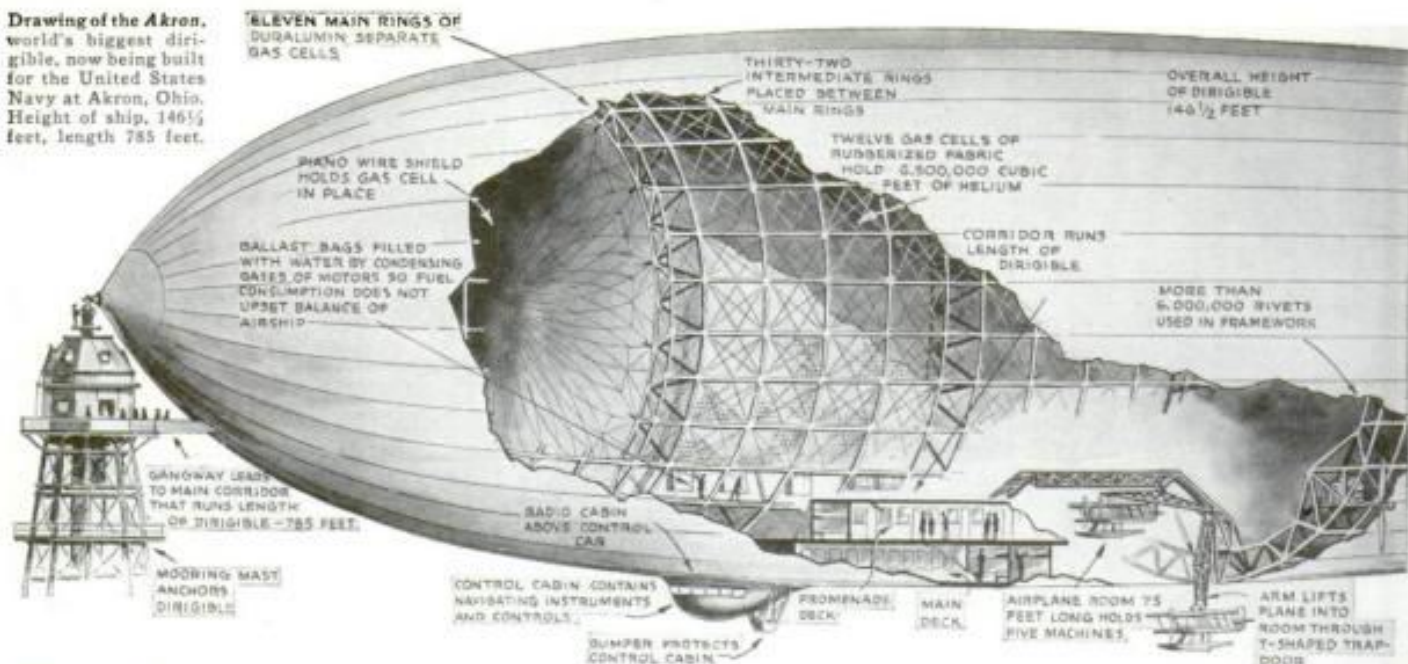


Cabin cars resemble prewar "roomettes," but are improved. "Budgette" offers single bedrooms for

about the price of a lower berth. Two bedrooms adjoining on same level can be thrown together.



Drawing of the Akron, world's biggest dirigible, now being built for the United States Navy at Akron, Ohio. Height of ship, 146½ feet, length 785 feet.



World's Biggest Airship to Fly in May

By
WALTER E. BURTON

ONE of the most successful shows in the world from the standpoint of attendance is now playing at Akron, Ohio. The stage is a nine-acre steel shell on the municipal airport, and the players are scores of expert workmen who climb, like so many monkeys, about the aluminum alloy framework that soon will be the Navy's new airship *Akron*.

Ever since it was decided to throw the Goodyear-Zeppelin airship dock open to the public, there has been a steady pilgrimage of the curious to this center of America's airship industry. Every day they come, regardless of weather. The

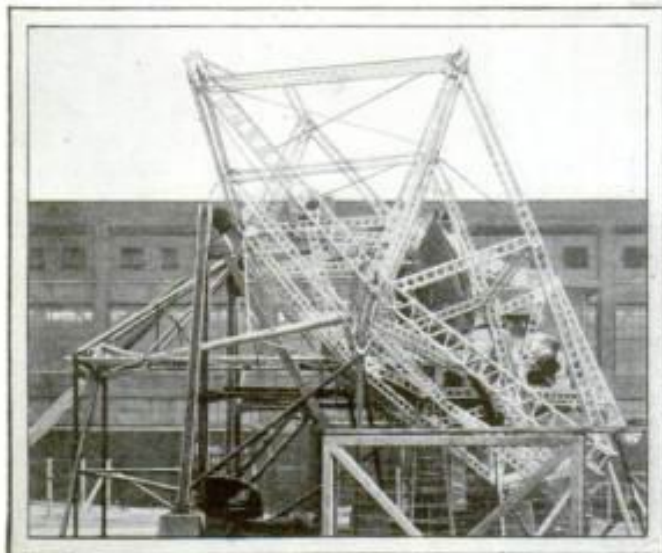
doorman at the dock checked 30,000 of them on a single warm Sunday late last fall. The following Sunday, with the temperature hovering about the freezing point, 12,000 were counted.

Every day, from nine in the morning to five in the afternoon, anyone may enter a fenced-off section of the airship dock and watch the



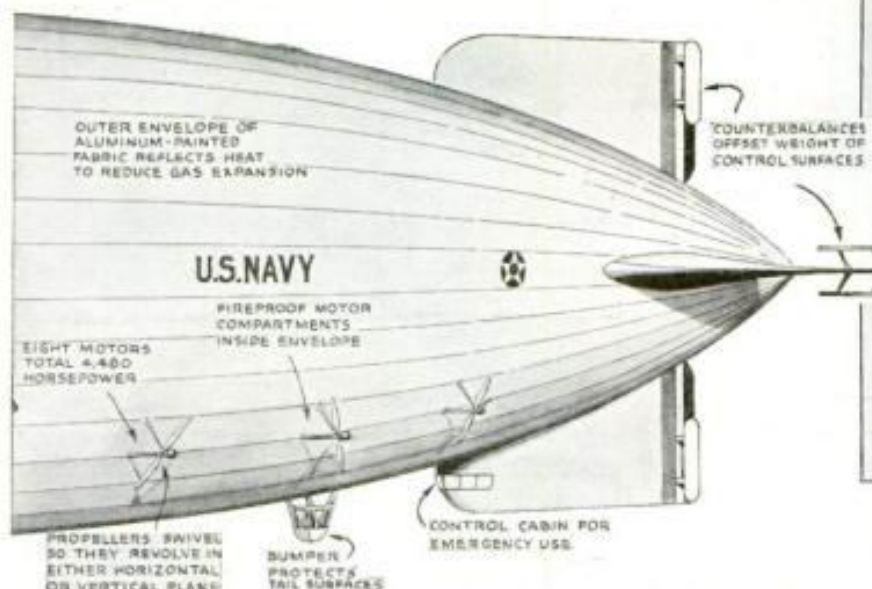
giant Zeppelin almost silently taking form. But what is there about the spectacle that attracts such huge crowds?

For one thing, the American public only once before has had the opportunity of witnessing actual construction of a rigid airship—that is, the *Shenandoah*, in 1921-23. Air-mindedness, coupled with curiosity, probably accounts for many of the visitors. But whatever the primary attraction, every spectator is impressed by the bigness of the dock—large



Above, a full size model of an engine room of the *Akron*, built for motor testing. At right, Dr. Wolfgang Klemperer, famous glider pilot, demonstrates to Dr. Karl Arnstein, designer, and Lieut. Settle, left, Navy inspector, one of ship's propellers.





Putting the girders in place and riveting them solid. The rivets are not hammered home but are forced tight with squeezers exerting 6,500-pound pressure.

enough to hold the National Capitol with room for a White House or two in addition—and of the airship, which will hold 6,500,000 cubic feet of helium.

Probably few of those who are not privileged to walk from one end of the dock to the other and inspect the vessel at close range obtain a truly accurate impression of size. For instance, from the floor the airship looks as if it were almost scraping the roof girders of the dock. But, if you were to ride up the crablike elevator that goes sidewise as well as up and down, you would find, upon viewing the busy scene from the catwalk 200 feet above the floor, that the top of the hull is actually several stories below your feet.

AT FREQUENT intervals on the busiest visiting days, a police officer turned orator tells the spectators about some of the features of the dock and the airship.

Someone inquires about the wires that look like the web of a giant spider. These wires are everywhere—lacing together the framework of duralumin girders that looks like a lacework of larger threads.

YOU could play a symphony on the bracing wires of the ship. The various lengths, diameters, and tensions employed cover a considerable portion of the musical scale. Steel piano wire, treated to make it corrosion-proof, is used throughout because it provides the greatest strength for a given weight. There will be between 1,250 and 1,500 miles of this wire in the completed ship!

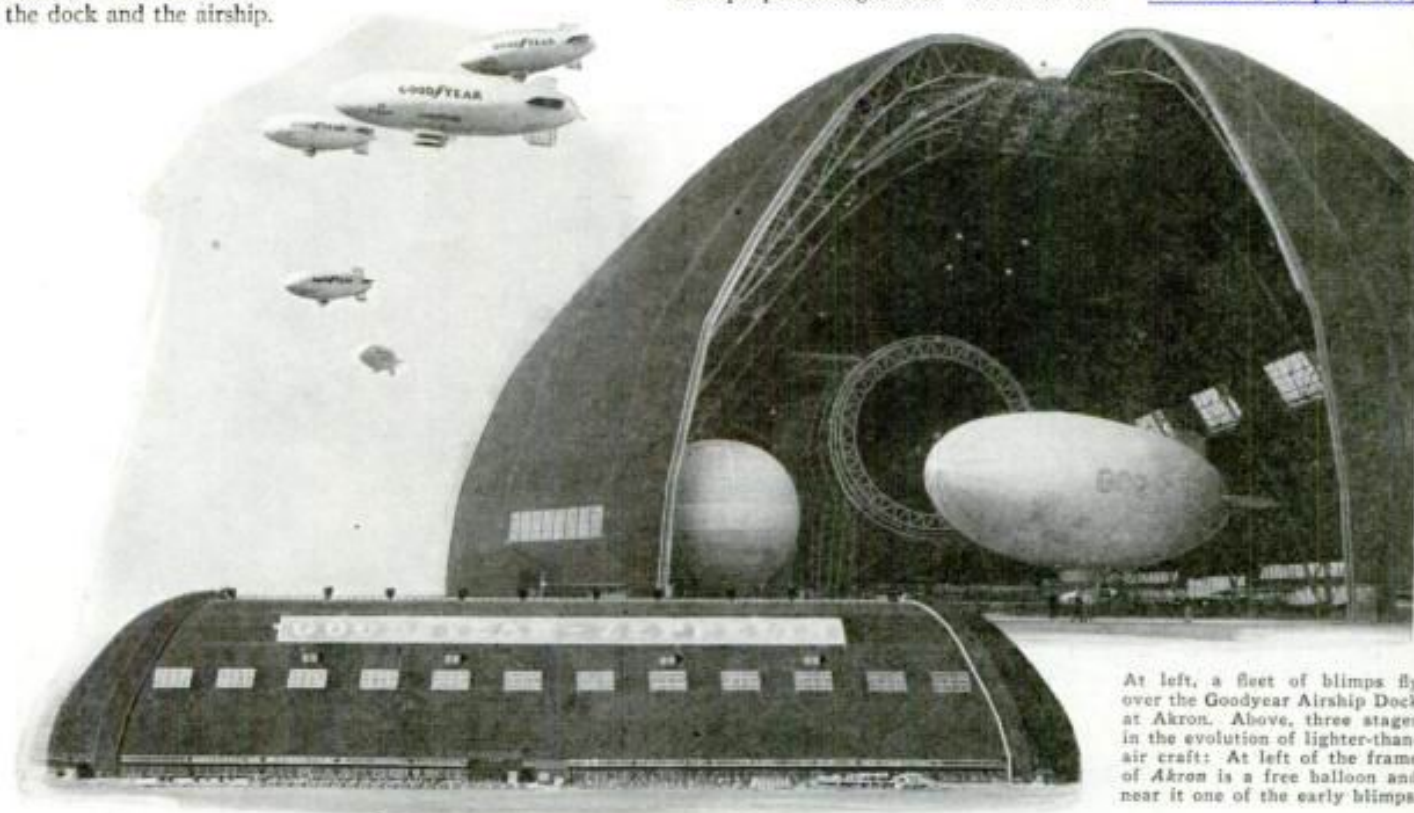
Nine different diameters, ranging from .047 to .135 inch, can be counted. The wire is all put under a tension that varies from fifty to two hundred pounds. As a result, the framework of the Zeppelin will have a rigidity and strength for all practical purposes as great as

if it were made in a single solid piece.

The largest wires are employed in the making of bulkheads—the network that separates adjacent gas cells. At the circumference of the huge, almost circular frames inclosing these cells, the bulkheads are attached to resiliency devices. These correspond to shock absorbers on an automobile. If a gas cell loses some of its helium, the adjacent cells will have a tendency to expand and fill up some of the space. The resiliency devices will serve to keep such expansion under control, yet permit an equalization of pressure.

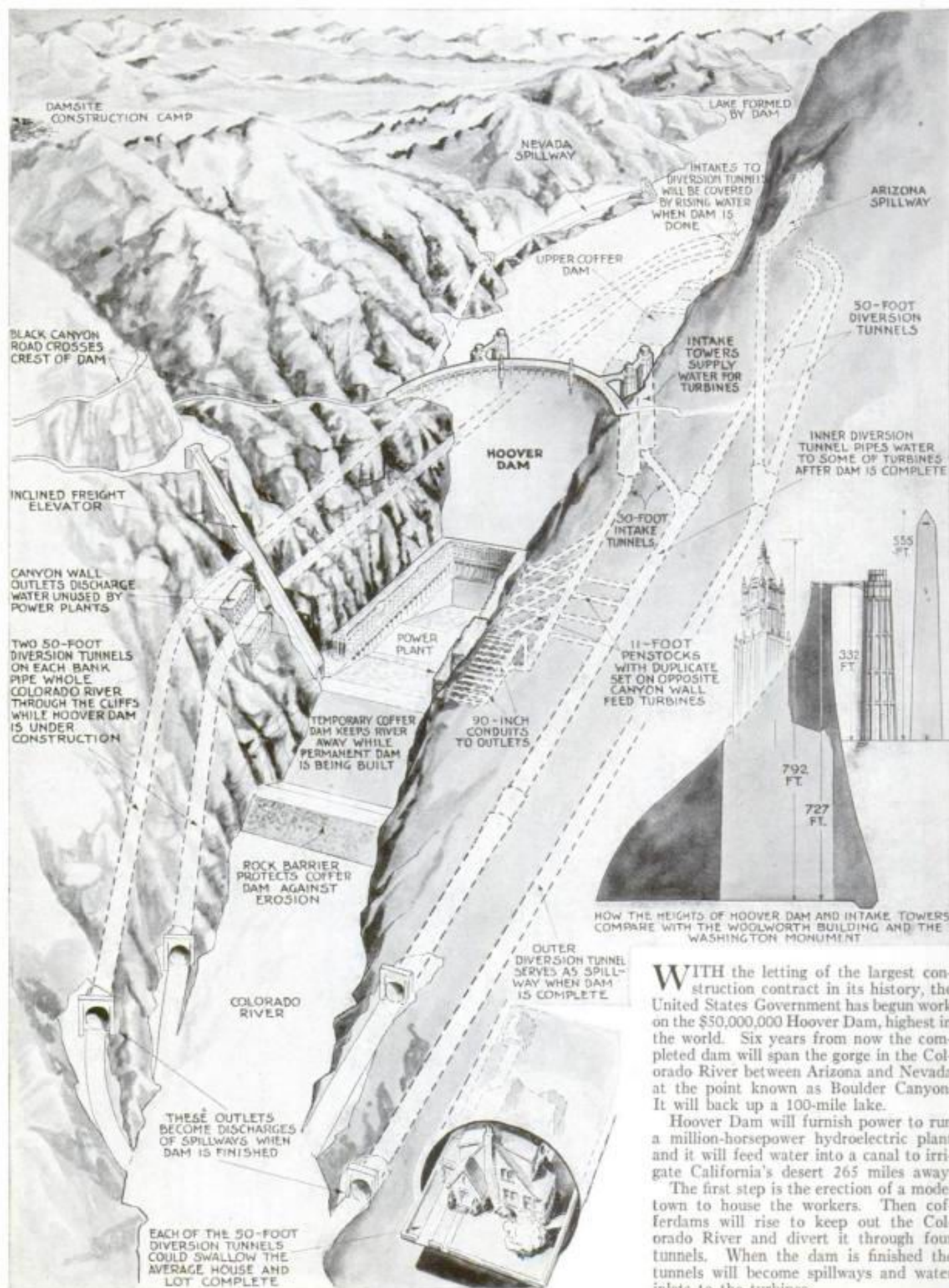
Perhaps you would ask, if you were visiting the dock, how the girders are fastened together. The answer is rivets—6,500,000 of them. It is a coincidence that there is almost exactly one rivet for every cubic foot of helium lifting gas the Akron will carry.

There is a little story behind those rivets. For one *(Continued on page 138)*



At left, a fleet of blimps fly over the Goodyear Airship Dock at Akron. Above, three stages in the evolution of lighter-than-air craft: At left of the frame of Akron is a free balloon and near it one of the early blimps.

World's Highest Dam Is Rising



HOW THE HEIGHTS OF HOOVER DAM AND INTAKE TOWERS COMPARE WITH THE WOOLWORTH BUILDING AND THE WASHINGTON MONUMENT

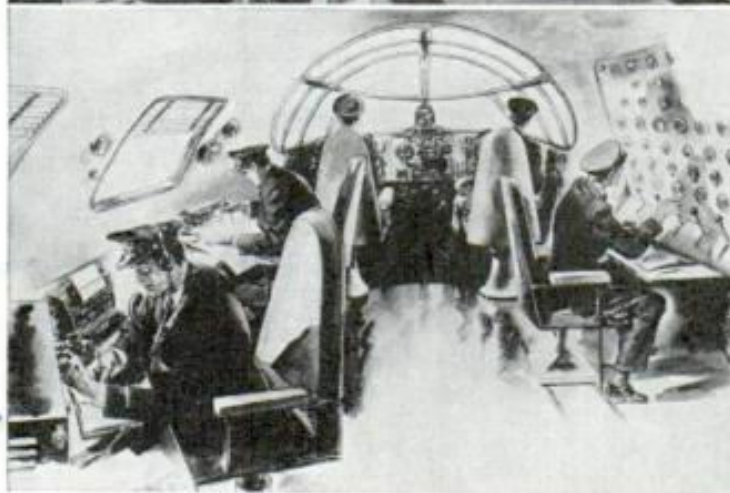
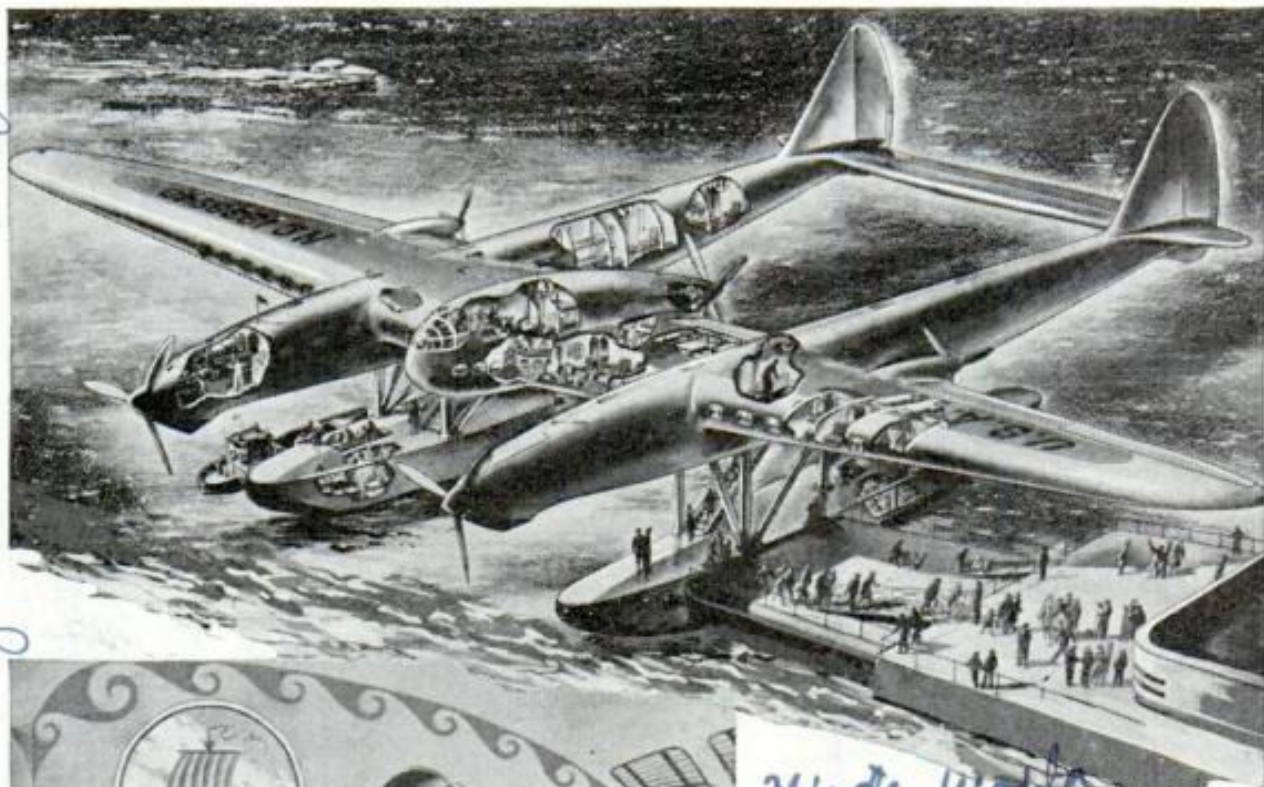
WITH the letting of the largest construction contract in its history, the United States Government has begun work on the \$50,000,000 Hoover Dam, highest in the world. Six years from now the completed dam will span the gorge in the Colorado River between Arizona and Nevada at the point known as Boulder Canyon. It will back up a 100-mile lake.

Hoover Dam will furnish power to run a million-horsepower hydroelectric plant and it will feed water into a canal to irrigate California's desert 265 miles away.

The first step is the erection of a model town to house the workers. Then cofferdams will rise to keep out the Colorado River and divert it through four tunnels. When the dam is finished the tunnels will become spillways and water inlets to the turbines.

H 354

Transatlantic 'Flying Wing' to Offer Luxury



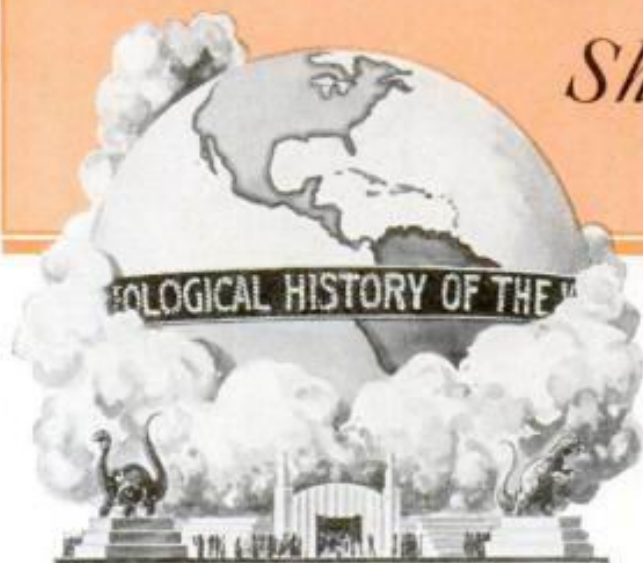
Cut-away drawing indicates ample accommodations in twin fuselages and wings for 120 passengers. This is the superliner proposed by Maj. Alexander P. de Seversky for transatlantic travel. Below are the lounge-observation room in leading edge of "flying wing," affording direct view ahead for passengers, and control room in central gondola

Wide World

Passenger accommodations aboard a super-clipper planned for transatlantic service will offer new luxury in air travel. The huge plane, literally a flying wing, will have dining saloon and promenade in two sections, each connected by a cocktail lounge and an observation deck. Observation windows in the leading edge of the wing will afford an excellent forward view. The two sections will have comfortable accommodations for fifty people, so that meals may be served quickly. The clipper is designed to carry a payload of 43,000 pounds and to accommodate 120 passengers. A crew of sixteen will operate the great craft, which will have a cruising range of more than 5,000 miles and a minimum cruising speed of 250 miles per hour. Supercharging will permit flight at high altitude. Passengers will be housed in the 250-foot wing, which is large enough to afford particularly spacious quarters. Attached to this wing will be two

Giant Metal "EARTH"

*Shows Life Forms
of All Ages*



On the outside of the great metal ball, within which will be shown all forms of life, will appear a complete world map

By EDWIN W. TEALE

A MAMMOTH metal globe, as high as an eight-story building, will represent the earth and house one of the most spectacular exhibits at the Chicago World's Fair, in the summer of 1933. Within it, mechanical monsters in a strange prehistoric zoo will reproduce scenes that took place millions of years before man appeared on earth.

The exterior of the ball will be covered with a map of the world. The oceans will appear in gleaming, silver-colored stainless steel and the continents in metal painted turquoise blue. The land areas are to be set out slightly from the globe and varicolored lights beneath will be turned on for night display. An electric sign, moving on a chain, will encircle the equator, announcing the attraction within.

At five-minute intervals, from vents around the base, puffs of live steam will be released to float upward like clouds. At night, colored lights will play upon the billowing white vapor. When viewed from the ground, this will give the impression that the huge globe is floating among the clouds.

Inside, four elevators will carry spectators to the main floor, fifty feet above the ground. Here, they will follow winding walks that lead past swamps of prehistoric vegetation and cliffs that form the natural setting for the giant animals. They will see woolly mammoths, saber-toothed tigers, extinct giant turtles, dinosaurs fifty feet long, and carnivorous monsters two stories high, all breathing, eating, and fighting as though they were alive.

CONSTRUCTED of wood, steel, canvas and papier-mâché, they will be operated electrically. Each will contain from one to sixteen motors, ranging in strength from one-eighth horsepower to two horsepower. In all, approximately 500 electric motors will be used to impart lifelike mo-

tions to the animals.

Expert operators at switchboards will make these huge creatures swing their heads from side to side, roll their eyes, lash their tails, and open and close their jaws. Hidden where they can see the crowds, these operators will frequently give spectators an

added thrill by having the monsters swing suddenly toward them with wide-gaping jaws.

Along the railings of the walks there will be hundreds of earphones. By means of them, spectators can hear lectures on the characteristics and habits of the particular animal before which they are standing. These lectures will be repeated continuously by the use of phonograph records in a central control room below. Earphones will be employed instead of loudspeakers so there will be no interference with the sound effects which will add realism to the exhibition. The huge mechanical animals will not only move, they will also "talk." Onlookers will hear the snarl of the saber-toothed tiger, the

hiss of the great brontosaurus, and the trumpeting of the prehistoric shovel-jawed elephant.

IN PREPARATION for this spectacular display, engineers of the firm of Messmore and Damon, New York makers of animated exhibition models, have been working for more than four years. Each animal is to be constructed the exact size of the beast it represents.

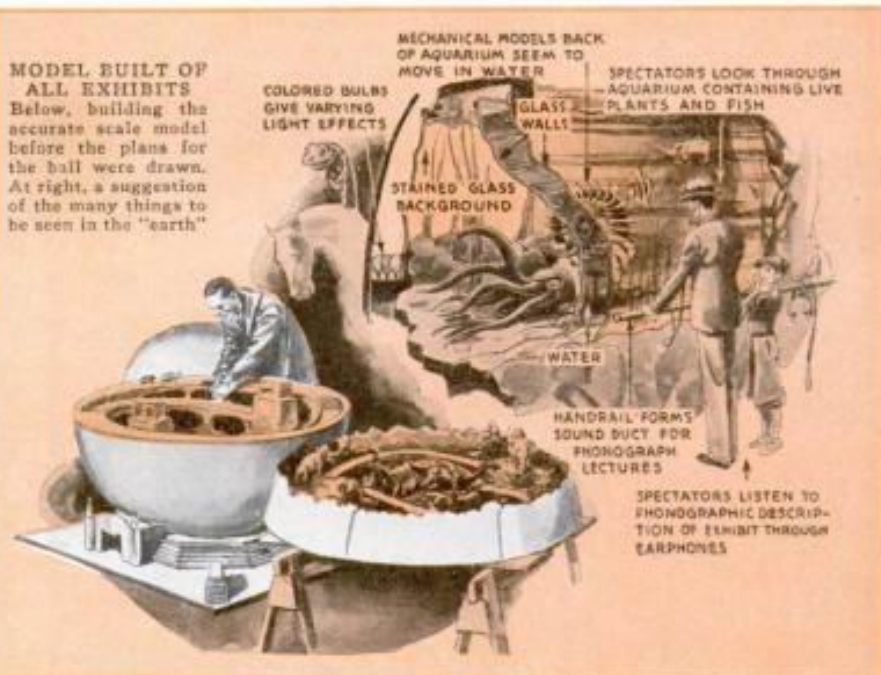
Realizing the educational value of the display, curators of the American Museum of Natural History, in New York City, have been cooperating to make the exhibits and their surroundings scientifically accurate.

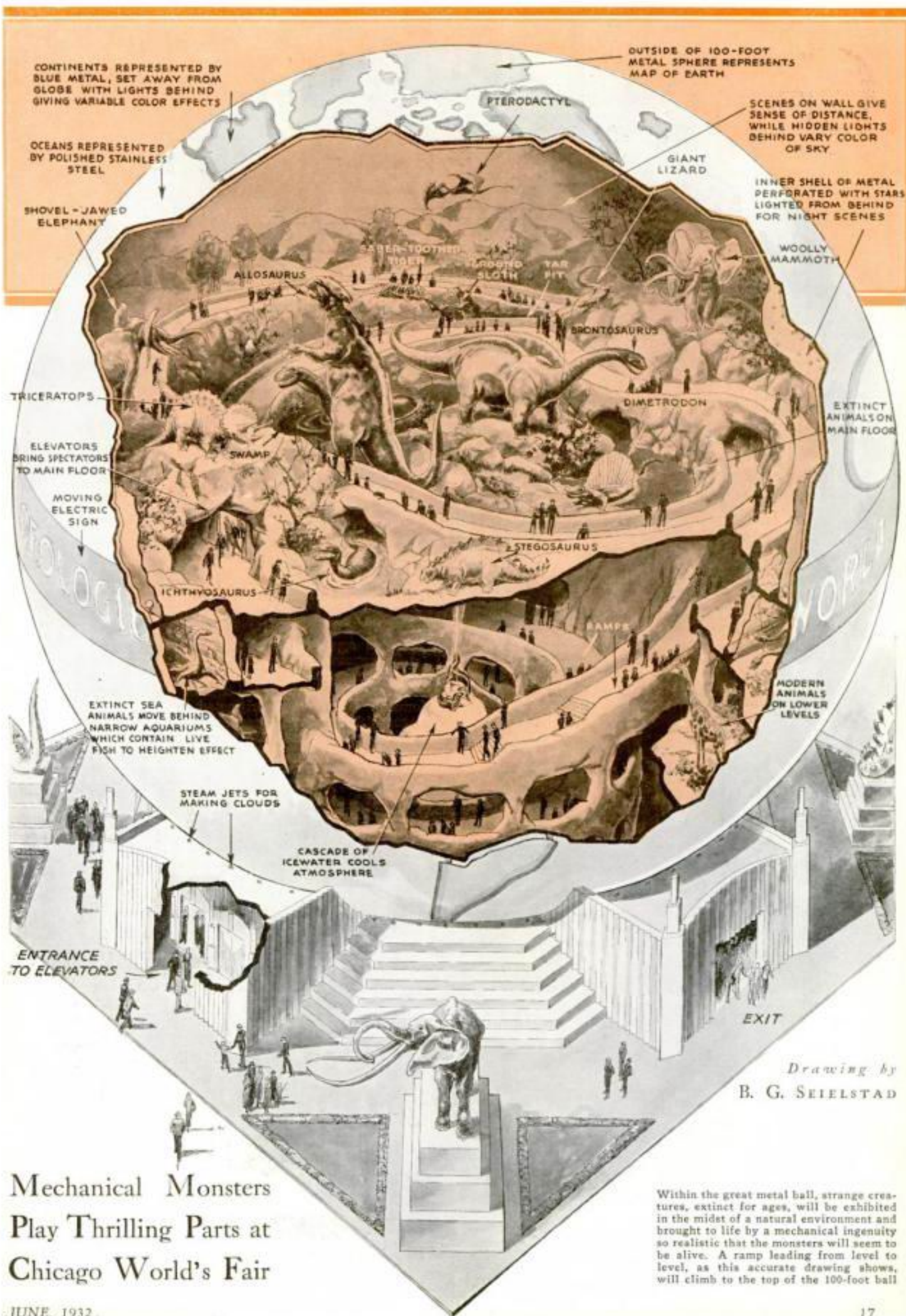
One of the features of the main floor will be a reproduction of a "Death-Trap of the Ages," a tar pit similar to the La Brea Pit, in California, where the bones of many extinct animals were found. It will show a giant ground sloth mired in the tar, struggling frantically to get free, while a tiger crouches on the bank ready to spring.

At the center of the hall, a meat-eating allosaurus, towering twenty-five feet high, with a great bone helmet protecting its skull, will be attacking a fifty-foot brontosaurus wallowing (*Continued on page 119*)

MODEL BUILT UP ALL EXHIBITS

Below, building the accurate scale model before the plans for the ball were drawn. At right, a suggestion of the many things to be seen in the "earth"





Mechanical Monsters Play Thrilling Parts at Chicago World's Fair

JUNE, 1932

Within the great metal ball, strange creatures, extinct for ages, will be exhibited in the midst of a natural environment and brought to life by a mechanical ingenuity so realistic that the monsters will seem to be alive. A ramp leading from level to level, as this accurate drawing shows, will climb to the top of the 100-foot ball



POPULAR SCIENCE MONTHLY

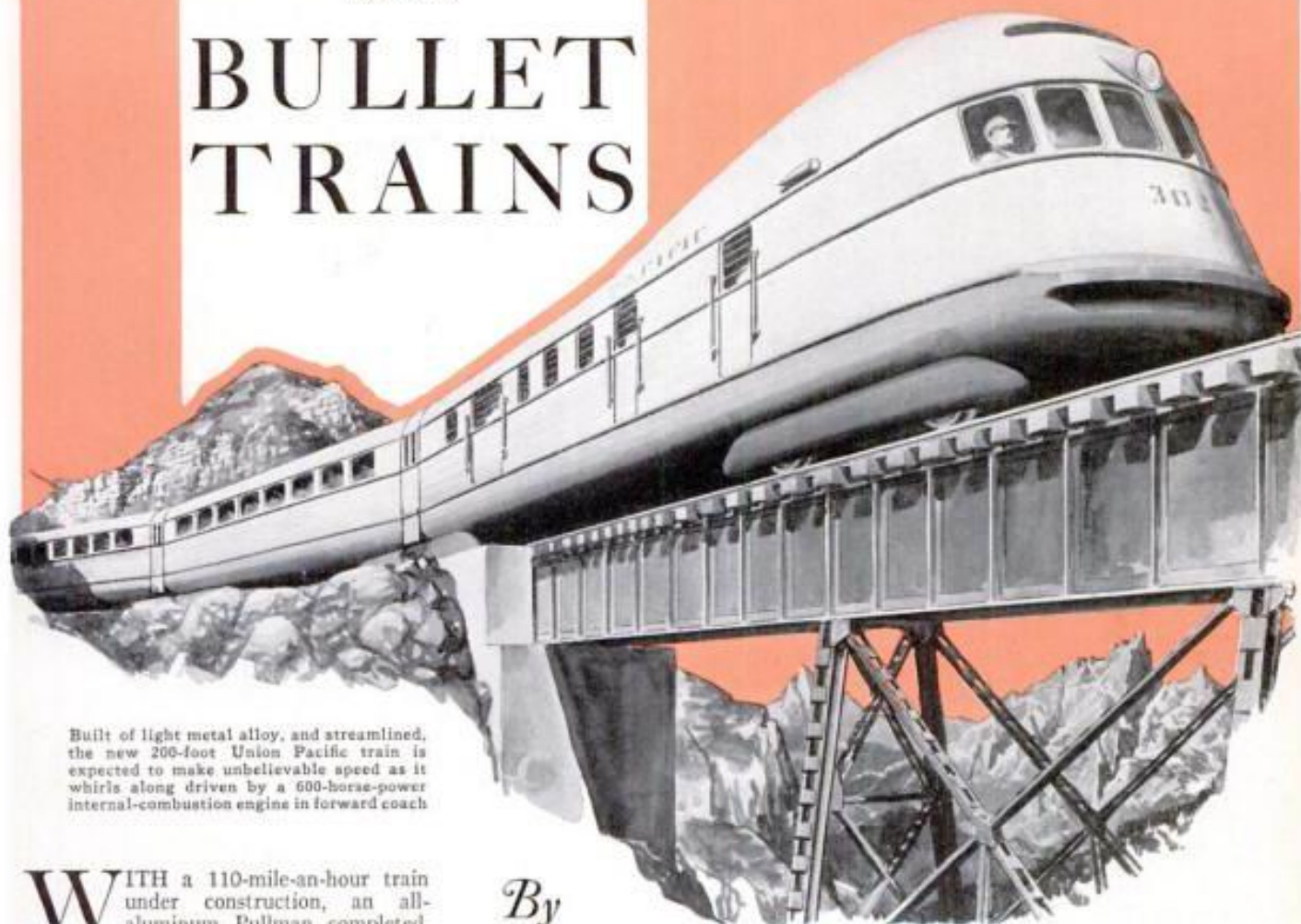
August 1933

Vol. 123, No. 2

RAYMOND J. BROWN, Editor



Railways' Fight for Lost Traffic Brings **Mountain-Top Road** *and* **BULLET TRAINS**



Built of light metal alloy, and streamlined, the new 200-foot Union Pacific train is expected to make unbelievable speed as it whirrs along driven by a 600-horse-power internal-combustion engine in forward coach

WITH a 110-mile-an-hour train under construction, an all-aluminum Pullman completed, bullet cars riding the rails in France and Germany, and an amazing mountain-top roadbed ready for service in California, recent months have seen record advances in railway equipment.

The race of the railroads to regain lost traffic is on. With faster, lighter, more efficient equipment, they are cutting costs and stepping up the speed of travel.

Like a 200-foot streamlined arrow, the new-type train designed for use on the Union Pacific is expected to skim over the rails at 110 miles an hour for short periods and to maintain a mile-and-a-half-

By
H. J. FitzGerald

a-minute clip on straight tracks. Accommodating 119 passengers, besides mail and baggage, the three coaches of the train will form a single streamlined unit weighing no more than one present-day Pullman. It will be driven by a 600-horsepower internal-combustion engine generating electricity in the nose of the forward coach. Sealed shatter-proof windows and special air conditioning ap-

paratus will eliminate all dust and noise.

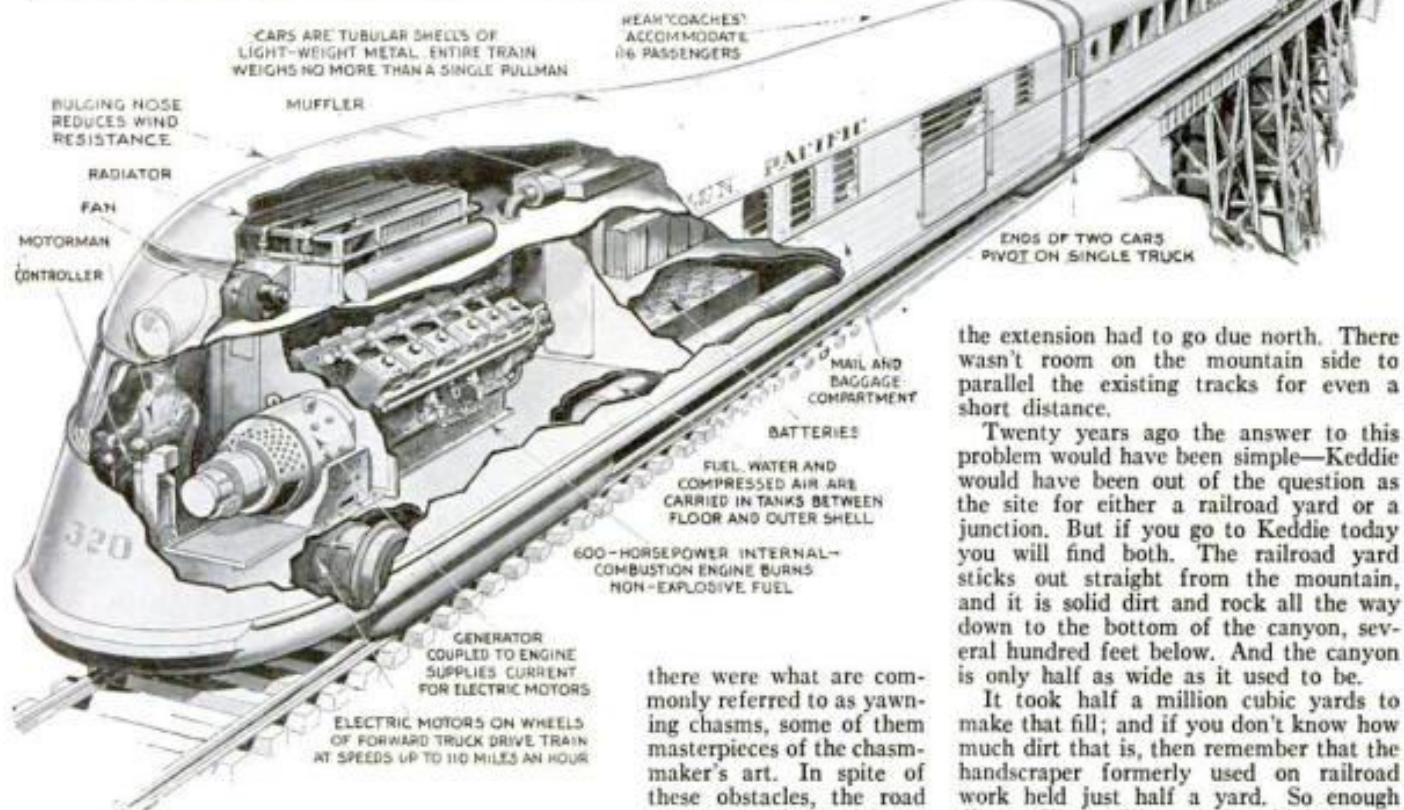
This radically new form of rail transportation is expected to be in operation within six months. At first, it will be used between large cities along the line, later going into service on the trans-continental run.

Another super-speed rail car recently touched 115 miles an hour on a straight stretch of track near Paris, France. The single coach is driven by four 200-horsepower racing automobile engines. It carries fifty-two passengers and at top speed makes two and a half miles on a gallon



AUTO ENGINES POWER TRAIN

The French coach, left, recently ran at a speed of 115 miles on tracks near Paris. It is powered with four 200-horsepower racing-automobile engines. It carries fifty-two passengers and makes two and a half miles on a gallon of fuel. Below, drawing shows the 600-horsepower internal-combustion engine as it is installed in the new Union Pacific aluminum, streamlined train.



the extension had to go due north. There wasn't room on the mountain side to parallel the existing tracks for even a short distance.

Twenty years ago the answer to this problem would have been simple—Keddie would have been out of the question as the site for either a railroad yard or a junction. But if you go to Keddie today you will find both. The railroad yard sticks out straight from the mountain, and it is solid dirt and rock all the way down to the bottom of the canyon, several hundred feet below. And the canyon is only half as wide as it used to be.

It took half a million cubic yards to make that fill; and if you don't know how much dirt that is, then remember that the handscraper formerly used on railroad work held just half a yard. So enough dirt to fill a million of the old-fashioned scrapers was taken out of the mountain-side and dumped into the canyon.

At Sheep Camp Gulch, the proposed line crossed a canyon and then pointed at the adjacent mountain. A ten-story building standing on the canyon bottom would just have reached to where the road was to cross, and a twelve-story building on top of that would just have permitted an observer on its roof to peak over the mountain top. The railroad builders, taking note of this situation, took off the top of the mountain and filled the canyon with it, bringing both to the same level.

The 110-foot fill not only overtops the tallest trees in the canyon, but it also overtops by a (Continued on page 95)

I dropped around in time to see the first railroad in the world that wasn't built by the power of mules!"

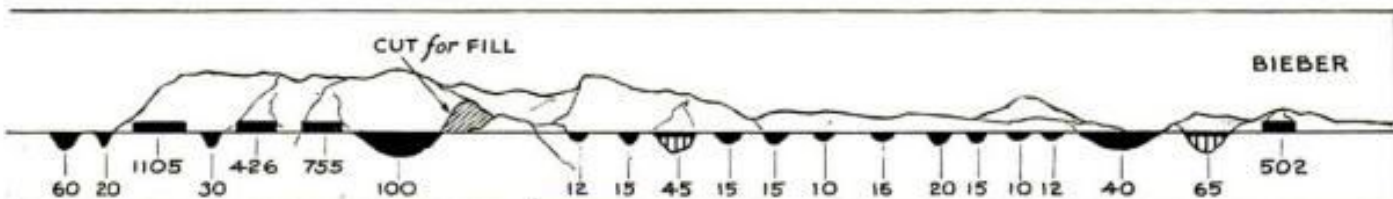
Machines have made it possible to run lines where it was impracticable, if not actually impossible, to run them before. In pick and shovel days, mountains were important obstacles. Railroads had to follow the passes and river courses or run into heavy grades and prohibitive costs. A route across a mountain range looked like a child's first efforts to write.

The prevailing topography of the country north from Keddie is, roughly speaking, straight up and down. When there weren't mountains in the way of the line,

there were what are commonly referred to as yawning chasms, some of them masterpieces of the chasm-maker's art. In spite of these obstacles, the road runs as nearly straight as many of those built close

to sea level on fairly smooth terrane. At the height of a mile, a road that tries to go straight and maintain a fairly horizontal position runs smack into one problem after another that would have baffled solution in the old mule-and-scraper days. This was the case at Keddie, where the extension takes off from the main line of the Western Pacific.

It was necessary to establish a junction there, and also a railroad yard. This seems simple enough until you look at Keddie. The town is half way up the side of a mountain promontory that sticks out into a couple of deep canyons. It is on the south side of the mountain and



length of the tunnels, the height of the trestles, and the depth of the fills on this recently finished line

Is This the Railway of the Future?

Super-Speedway for Trains, Planes, and Motors

AIRWAYS, highways, and railways are combined in a startling plan of high-speed transportation advanced by Justus W. Fry, railroad and electrical engineer of Seattle, Wash. He proposes to link important cities with a multiple traffic artery in the form of a three-deck elevated viaduct of steel and concrete. The roof of this structure, in a design that he has patented, offers a continuous emergency landing platform for airplanes and airships, and also guides pilots flying overhead. A tier immediately beneath the roof provides a super-speedway for automobiles, always dry and free of cross traffic. Railway tracks occupy the ground level, while high-speed

MULTIPLE TRANSIT ARTERY LINKS LARGE CITIES BY ROAD, RAIL, AND AIR

TRANSPORTATION BUILDING HOUSES PASSENGER AND SERVICE STATIONS

Continuous airplane runway permits emergency landings

UNDER-PASS FOR LOCAL TRAFFIC

Speedway for automobiles

High speed monorail cars

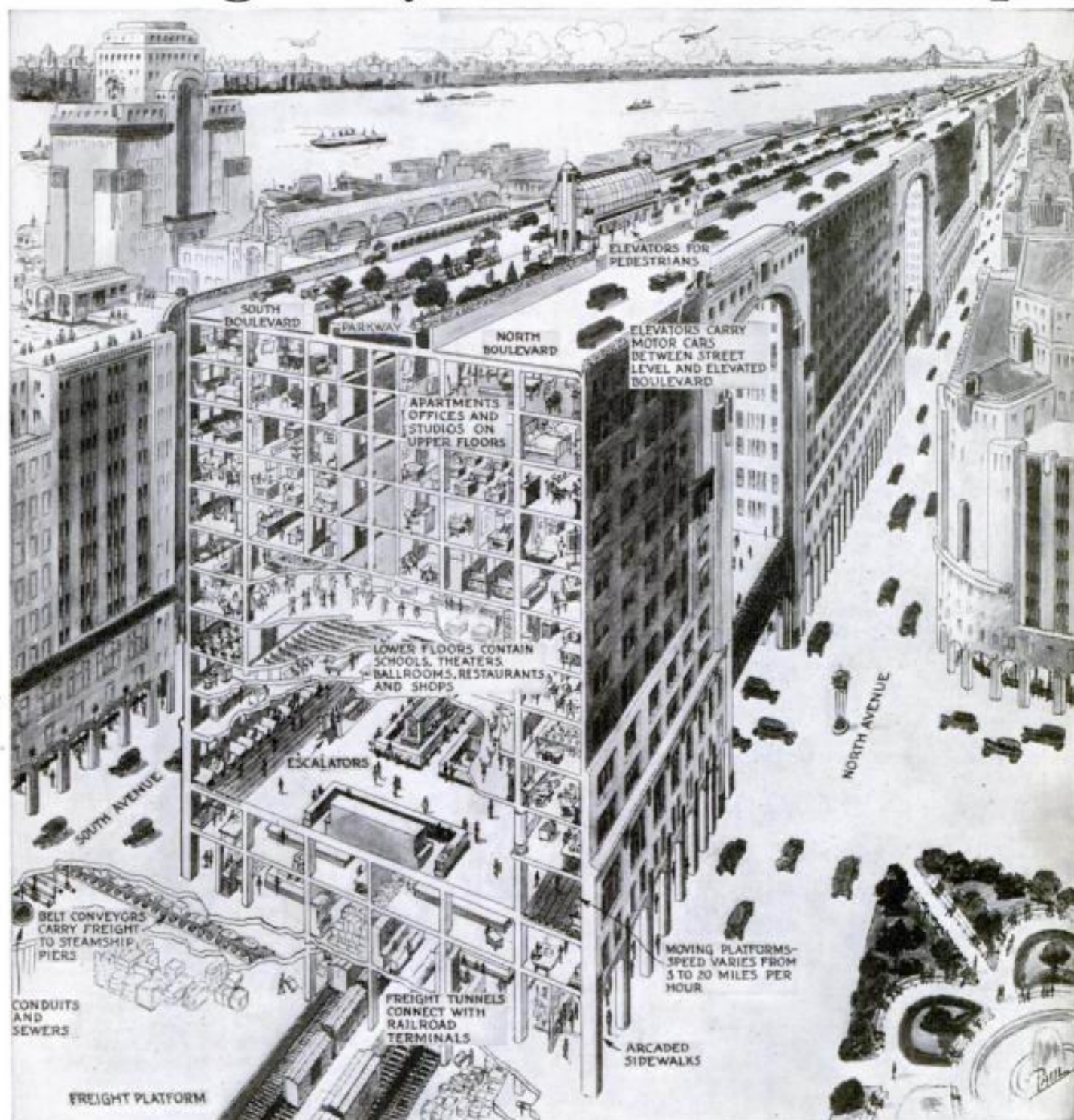
Express highway for trucks and buses

Railway tracks at surface level

monorail cars with air propellers, making non-stop runs of 300 miles or more along tracks at the side of the structure, provide super-express passenger service. Such a structure, Fry maintains, keeps pace with the growing demand for relief from traffic congestion and for swift cross-country travel. It also has significance from the viewpoint of national defense, since in time of war it would provide a highly efficient military roadway for rapid and secret movements of troops. Railway companies might logically take the initiative in constructing such arteries, according to the designer, since they already own the right-of-way and have established the necessary passenger and freight depots. By expanding their activities to set up a coordinated transit system on his plan, they could, he suggests, offset inroads made into their business by the growing competition of buses, motor trucks, and airplanes. Tolls would be collected from private vehicles, while the railroads themselves could control the bus and trucking services. Initially the unified transit arteries would be built in the most densely populated regions of the country.

This is our artist's conception of the three-deck viaduct designed to carry fast rail and motor traffic between large cities. The roof provides an emergency landing field for aircraft

A Highway on the Roof Tops



New York Engineer Proposes 16-Mile Elevated Speedway as Traffic Aid

OUR artist pictures here an ingenious new plan for solving New York City's traffic problems by a remarkable system of roof-top boulevards running more than sixteen miles in a straight line through the heart of the city. Bridging of cross streets for free movement of traffic; moving platforms for speedy and convenient passenger service; healthful elevated playgrounds for children; underground railway freight service—these are some of its outstanding features.

The proposed system, conceived by John K. Hencken, a New York engineer, has been approved by a number of emi-

nent engineers and city planners. They say it is entirely feasible from an engineering standpoint. It calls for a series of buildings of uniform twelve-story height extending from the lower tip of Manhattan Island to Yonkers, connected by bridges at all cross streets.

Sub-basements would contain four railroad tracks for freight service, as well as conduits and sewers. The first floor, arched to form a ten-foot sidewalk, would be devoted to stores and shops.

Through the second or main floors, continuous moving platforms for free passenger service would run at graduated

speeds ranging from three to twenty miles an hour. These platforms also would be carried on bridges over cross streets. Other lower floors would be occupied by retail shops, restaurants, theaters and so on. The upper floors would be used in business sections for offices; in residential districts for apartments and studios.

North-bound and south-bound boulevards on the roof-tops would be separated by a protected parkway, reached by elevators. Other elevators, in every block, would carry motor cars from the street level to the elevated boulevards.

Winners or losers?

Energy experts evaluate

13 wind machines

Giant twin-bladed mills are only one goal of our wind-energy effort. Here are some bizarre, but promising, alternatives

By VICTOR CHASE
DRAWINGS BY RAY PIOCH

As you read this, the conventional propeller is king in harnessing energy from the wind. But the day may come when it is overthrown by a few electrically charged drops of water, a spinning tower on a flatbed railroad car, a huge tower with a relatively small rotor inside, or a machine that looks like a giant upside-down eggbeater.

For the time being, however, the conventional, horizontal-axis wind-energy conversion system (WECS) is hogging the spotlight. In the July '74 issue, PS reported on the Department of Energy's (at that time NASA/NSF's) Mod-O prototype 125-ft.-dia. propeller-type mill erected in Sandusky, Ohio. A production model of that turbine is now delivering 200 kW in Clayton, N.M. A larger version, with 200-ft. blades, will generate 2000 kW on a mountaintop site near Boone, N.C., within the next few months. Still to come is a 2500-kW model, whose blades will span 300 feet [PS, Jan.].

Even the people at DOE's Wind Energy Systems Branch, who are funding the development of many strange wind concepts, admit that the odds of successfully challenging these large propeller wind generators are slim. But

the money flows nonetheless in the hope that from the dark-horse pack a big winner will emerge.

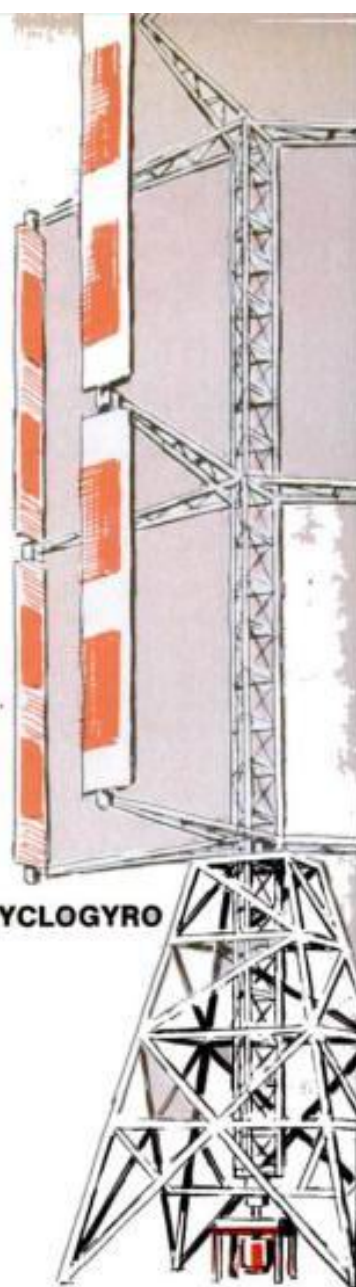
As Dr. Peter Moretti, who oversees the advanced wind-concepts program at DOE, puts it, "We're trying to cover all of our bets and look for a breakthrough to be sure we don't miss anything."

While DOE is hedging its wind-energy bets, it is not doing so like a wild-eyed gambler. Louis Divone, head of DOE's wind-energy program, explained the philosophy: "The risks one takes are proportional to the possible improvement. If the concept looks like it will improve the output only 10 percent, we would have to be very sure it will work before we invest the funds in it. But," he added, "if it looks like it will double or triple the efficiency, then it may be worth more of a gamble."

Summing up his department's quest for a better wind trap, Divone told me, "Basically anything will work. Any asymmetrical device you can make rotate, translate, or oscillate can generate electricity, run pumps, air compressors, and so on. It's how much power you can get in what wind for how much money. That's the key question."

All of the seemingly oddball approaches aimed at beating the wind-energy odds can be placed in four categories: vertical-axis windmills; augments windmills; windmills that are low in cost; and, finally, the "far-out" concepts. In all, 13 different designs are now being funded by DOE, and they're all described in the following pages.

CYCLOGYRO



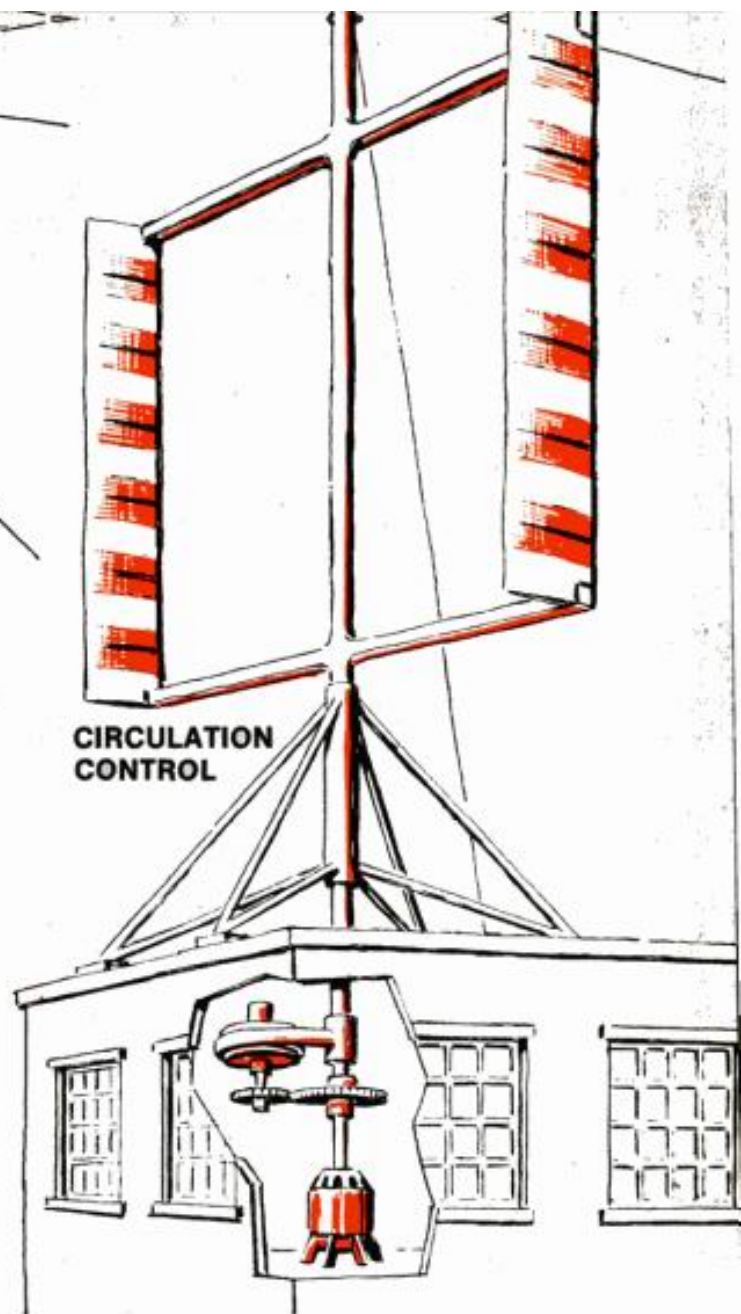
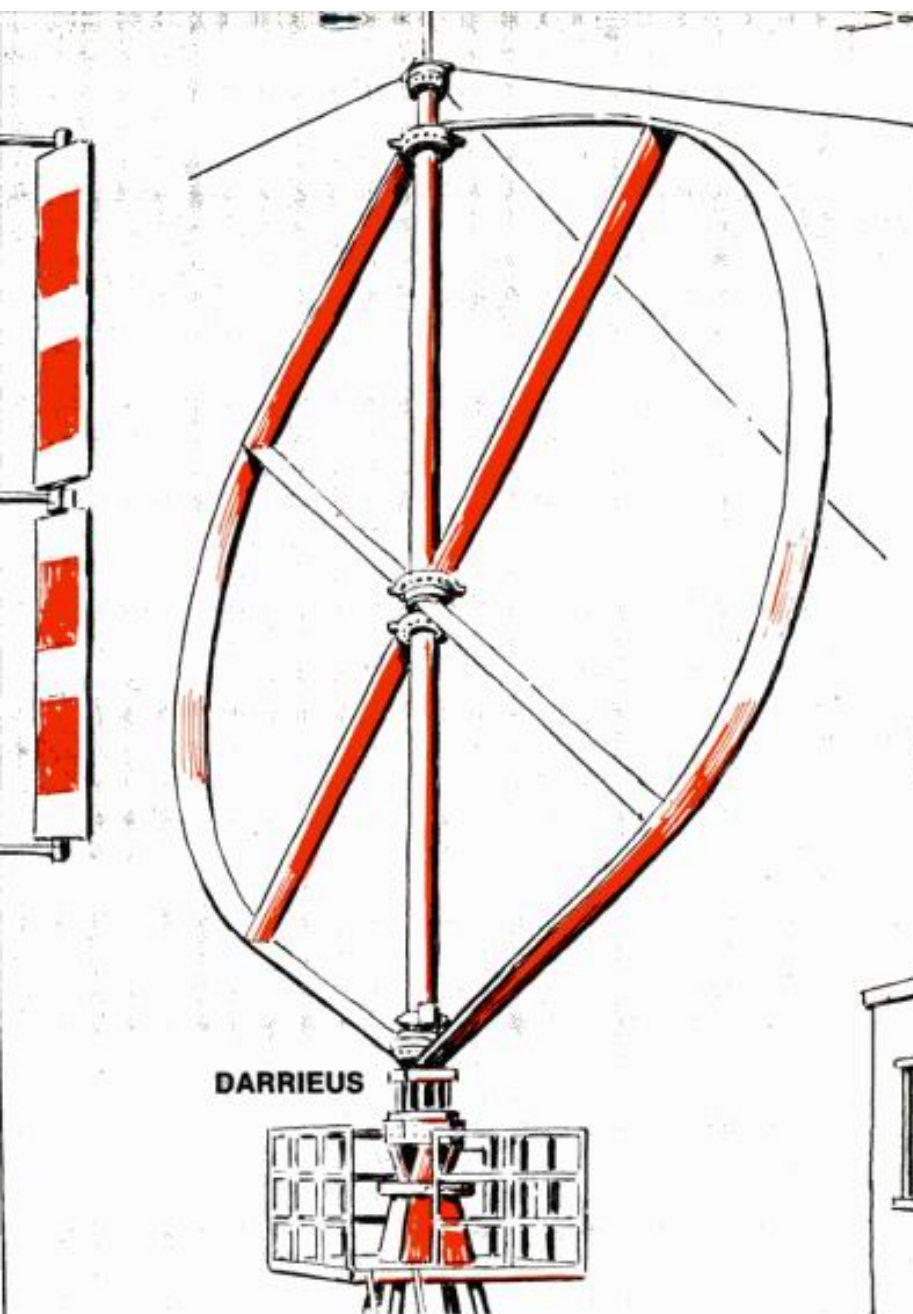
VERTICAL-AXIS WINDMILLS

Of all the advanced concepts, the vertical-axis machines are considered by many experts to hold the most promise. The primary advantage of these designs is that, unlike horizontal-axis windmills, they do not require a yaw control to turn the machine into or away from the wind. This cuts costs.

Darrieus

The Darrieus is by no means a new design. French inventor G. J. M. Darrieus applied for a U.S. patent on his vertical-wind-machine idea in 1925, and a patent was granted six years later. The design then languished for some 45 years until it was rediscovered by the National Research Council, Ottawa, Canada, during the early 1970's. In 1974 engineers at Sandia Laboratories, Albuquerque, N.M., also started work on the Darrieus concept [PS, May '75].

Its blade is shaped much like an aircraft wing with the leading edge slightly thicker than the trailing edge. In the case of an airplane, aerody-



dynamic forces acting on this airfoil provide lift. With the Darrieus wind turbine, the airfoil drives the blades into the wind regardless of its direction. Each Darrieus blade is curved in the symmetrical shape a rope would take if spun around a vertical axis.

A major advantage of the Darrieus design is that the blades do not require a variable-pitch mechanism to protect them from damage in high winds.

To strike a balance between cost and performance, windmills are designed to obtain power from winds within certain speed ranges. When wind speed exceeds the maximum that the mill is designed to handle, the propeller feathers (is positioned at an angle to the wind so that it no longer turns). If this did not occur, the propeller would continue to speed up and the machine would eventually be destroyed. Because of their aerodynamic characteristics, the Darrieus blades go into a stall in high winds.

But while the Darrieus windmill has this positive no-pitch characteristic, it will not start itself like a horizontal-axis machine does. Just like an airplane's wings, Darrieus blades will not create lift until brought up to

speed. A starter is needed to get the thing going. In the latest Sandia mills, the generator doubles as a starter.

There are other trade-offs between the Darrieus and conventional wind turbines. On the pro-Darrieus side, the machine delivers mechanical power to the base of the shaft, allowing heavy power-generating equipment to sit on the ground. With horizontal machines the generator is usually located in a nacelle behind the rotor, requiring a heavier, more costly tower.

On the negative side, the Darrieus tends to run at lower rpm than horizontal-axis machines. This property requires more costly transmissions. Probably the biggest strike against the Darrieus, though, is the fact that it has a somewhat lower aerodynamic efficiency than conventional machines.

Dr. Richard Braasch, Sandia's advanced-energy-projects division supervisor, puts the problem this way: "If you have lower efficiency and lower cost, does the cost go down lower than the efficiency?" While no one knows for sure, "all studies to date suggest that cost will go down more rapidly than efficiency," says Braasch.

Currently, Sandia has three Darrieus

machines up and running. One is about six feet in diameter, another 15 feet, and the largest is 55 feet in diameter. In each case, the height is about equal to the diameter. The largest one produces 60 kilowatts of electricity in a 28-mph wind, and 30 kilowatts in a 22-mph wind. (Alcoa was recently granted a \$335,000 contract to develop an eight-kilowatt Darrieus machine.)

Cyclogyro

Another vertical-axis-type machine is the cyclogyro. One model is currently on the market for a breezy \$5500, plus tower, which runs about \$1000. The cyclogyro has straight, variable-pitch blades that give it several advantages over the Darrieus. First, it is a self-starter. Second, controlling the pitch permits the extraction of a greater amount of power. Wind-tunnel tests indicate that the cyclogyro has a better power coefficient (greater efficiency) than the Darrieus at lower rpm. The straight cyclogyro blades may also be cheaper to manufacture.

The unit now on the market has three eight-foot-tall blades with a total diameter of 12 feet. It can produce four

Continued

kilowatts in a 30-mph wind, and two kilowatts in 24 mph. Known as the Cycloturbine, the machine is manufactured by Pinson Energy Corp. (Marston Mills, Mass.). It was designed by Herman Drees, president of Pinson, who while a graduate student at MIT in 1975 received a grant through SCORE (Student Competition for Relevant Engineering) to pursue the idea. Recently Pinson and the research firm of Aerospace Systems, Inc., Burlington, Mass., have been awarded \$365,000 to develop a one-kilowatt version.

Another cyclogyro, known as a Gyromill, has been undergoing development for several years by the McDonnell Douglas Corp., St. Louis, Mo. At present, a wind-tunnel model of this device is in existence.

Circulation control

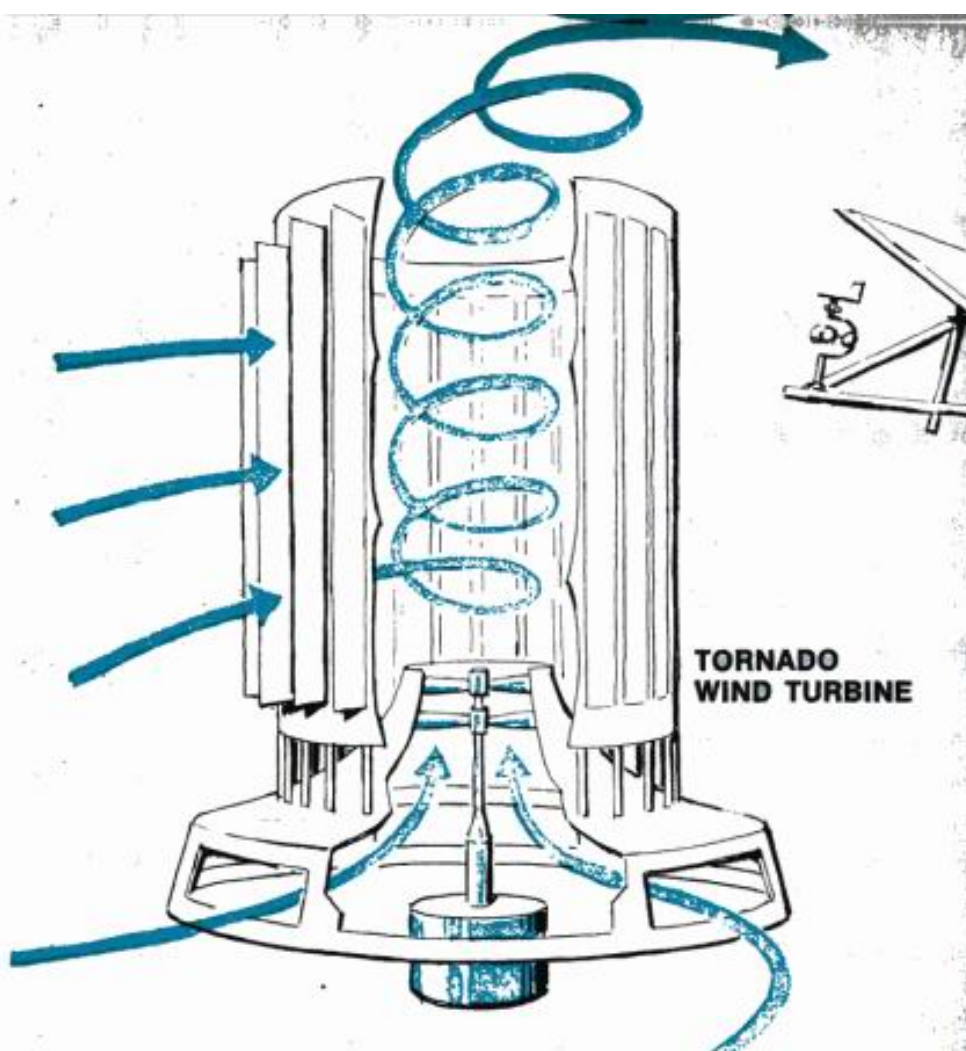
Another DOE-funded vertical-axis design goes by the name of Circulation-Controlled Vertical-Axis Wind Turbine. Still in the conceptual stage, this design has the same basic configuration as the cyclogyro, but the rotors are designed to take advantage of a unique STOL (short takeoff and landing) aircraft-wing design known as the circulation-control wing. The wind-turbine concept is being developed by Dr. Richard Walters of West Virginia University's Department of Aerospace Engineering.

Here's how both the wing and wind turbine rotor work: The trailing edge is rounded instead of having the conventional knife-edge configuration. High-pressure air is blown over this trailing edge. The air adheres to the trailing edge, then shoots off sideways. In the case of an aircraft this acts like a flap, causing the air to flow downward, giving increased lift. It is expected that the use of the same configuration on a vertical-axis cyclogyro rotor will both increase the torque (power) at a given speed and allow the turbine to operate at a lower optimum speed.

Dr. Walters told me, "We can operate slower at higher efficiencies. This is important because it cuts down the centrifugal forces greatly, and it's structurally easier to build a machine that goes slower."

While an airplane using the circulation-control concept has been built and flown, a wind turbine with such rotors is still on the drawing boards. The configuration Dr. Walters visualizes would pressurize a hollow vertical shaft via a compressor. The pressurized air would be run out to the blades through the struts holding them in place. The air would be fed into the blades and come out through slots.

Although some power will have to be sacrificed to drive the compressor, Dr. Walters feels the trade-off will be worthwhile. "Theoretically, we're looking at an overall efficiency in the range of 40 to 60 percent, operating at about half the speed of a conventional-blade vertical-axis machine." The Darrieus gets 20 to 40 percent, while propeller types are operating in the 40 to 45-percent range.



AUGMENTER WINDMILLS

The idea behind augments machines is to get more out of the propeller. Then the propeller can be shrunk in size, reducing costs. However, additional static structures are usually needed to increase the wind speed the propeller "sees." It remains to be seen if the cost of these structures will be justified by the reduction in propeller costs.

Diffuser augments

The oldest, and probably the most promising for the near future, is the diffuser-augmented wind turbine undergoing development at Grumman Aerospace Corp., Bethpage, N.Y.

"The idea of ducted wind turbines is over 100 years old," Dr. Richard Oman of Grumman told me. "It's been reinvented every 20 years or so, and we're one of the reinventors."

Under the diffuser concept, a shroud (static diffuser) is placed around a more or less conventional horizontal-axis rotor. The diffuser is narrow at the point it faces into the wind, and expands as it goes back. This configuration creates a pressure drop behind the rotor blades, causing increased airflow through the propeller.

The major problem that developers have encountered is that the airstream has been breaking up as it passes through the diffuser, reducing efficiency. To counter this effect the divergence angles of the diffuser have to be

quite small, requiring a costly shroud.

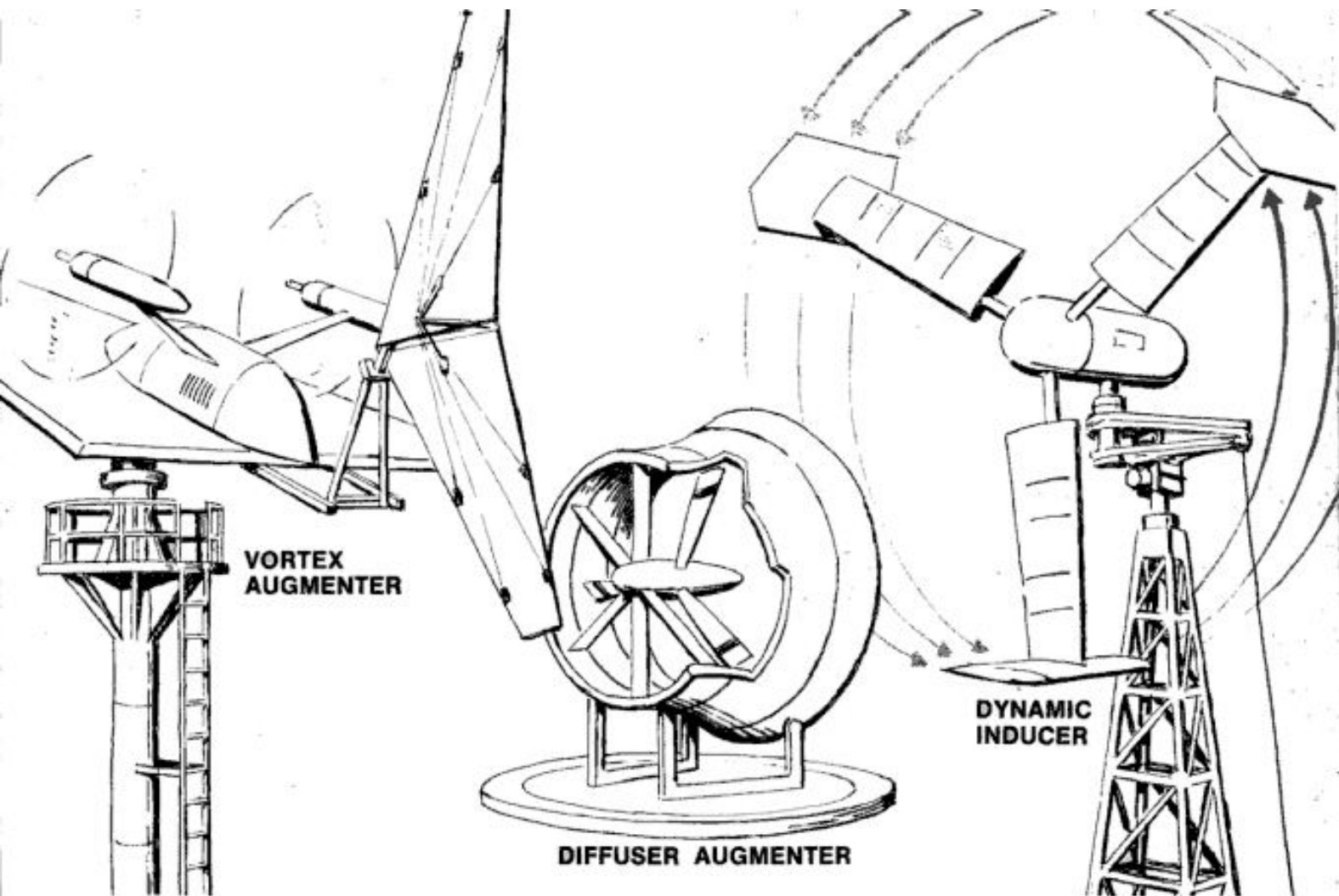
The Grumman researchers are working to design a small yet effective shroud using modern fluid-dynamic techniques. They hope that by putting slots in the diffuser to introduce external air into the internal wall of the diffuser they can counter the tendency toward stalling. To date they have conducted wind-tunnel tests showing they can squeeze about $3\frac{1}{2}$ times the power out of a wind turbine with the diffuser than could be obtained from a conventional rotor.

Yet the diffuser must be made strong enough to withstand strong winds. Can that be done at the right price? "We have yet to prove that we can construct the machine with all the hard truths of engineering reality for fewer dollars than a conventional machine," says Dr. Oman.

Dynamic inducer

To get away from the potential high cost of the diffuser structure, noted aerodynamicist Dr. Peter B. S. Lissaman is working on a dynamic inducer that does much the same with a dynamic (moving) apparatus as the Grumman concept does with a static device. The dynamic inducer consists of a small T-shape device appended to the tips of the rotor blades of a conventional horizontal-axis machine. This configuration pushes air out away from the propeller, thereby causing more air to be drawn into the propeller, creating higher efficiency.

Relating this design to the diffuser duct, Dr. Lissaman explained that if



one were to "take the duct and join the propeller to it, then cut slices out of the duct and throw away the pieces except for the ones that were attached to the propeller, he would have these little tip vanes on the propeller."

Because these "duct sections" are rotating they need be only about one-hundredth the area of the duct to do comparable work. To illustrate this concept, Dr. Lissaman asked me to consider the wing of a small airplane. "It has got to produce so much lift," he said. "Now consider the rotor of a helicopter. It is only about one-hundredth the area, but it produces the same lift because it's going around."

But, even with this concept, the fact that you can't get something for nothing makes itself apparent: It takes power to drive the tip vanes around because of their drag in the air. The challenge is to minimize that drag.

The idea for this wind-energy device was first conceived by Professor Theodore Van Holten at Delft Institute of Technology, Holland. Dr. Lissaman, a vice-president of AeroVironment, Inc., Pasadena, Calif., and a co-designer of the Gossamer Condor man-powered aircraft [PS, Oct. '77], heard about Van Holten's work two years ago.

Now Dr. Lissaman is conducting field tests with a commercially available Kedco wind machine on which he has mounted the dynamic-inducer tip vanes. The conventional Kedco has a 12-foot diameter and a three-bladed rotor, and is rated at 1200 watts in a 21-mph wind. Of his work, Dr. Lissaman says, "We have not proved the

concept practical, but we are hopeful."

Vortex augmenter

As is often true, the idea for this highly innovative wind-energy concept evolved as the result of work its inventor had been doing on aircraft. Specifically, Dr. Pasquale Sforza, professor of aerospace engineering at Polytechnic Institute of New York, Farmingdale, had been doing research on aircraft wakes.

He knew that the passage of air over a wing creates vortices (whirlwinds) which contain much kinetic energy. It was Dr. Sforza's idea to capture this energy by constructing a delta wing on which he would mount two rotors. As the air passes over the wing, vortices are formed, thus concentrating the wind energy before it reaches the rotor. "With a good design you can almost double the wind velocity," the inventor explained.

Under DOE sponsorship Dr. Sforza completed an 18-foot-long, 10-foot-wide (at the base) operating model of his idea. It has two three-foot-dia. rotors. (An artist's concept of that model is featured prominently on this month's cover.) Dr. Sforza has been pleased with the results of the experiment so far.

There are numerous advantages to this wind-machine design. The augmentation allows deriving more energy from smaller rotors, and rotors are a major part of a wind machine's cost. Also, because the wind speed seen by the rotors can be varied by either altering the angle of attack of the wing surface or by controlling a small flap

on the back of the wing's surface, the need for a variable-pitch rotor is eliminated, again slicing the cost of the rotor. An inexpensive yaw control is another plus. The vertical stabilizer points the wing into the wind.

Tornado wind turbine

This design is the offspring of Dr. James Yen of the Grumman Aerospace Corp. Bethpage, N.Y. [PS, Jan. '77]. It is still in the wind-tunnel-test stage, but the inventor of the device predicts that his machine may be able to augment the power in the wind by a factor of up to 1000.

Dr. Yen's system consists of a tower with operable vertical vents. The vents on the side toward the wind would open while those opposite the flow would close. As the wind blows into the tower it would spiral toward the top, creating a miniature tornado (vortex). In the center of this vortex is a low-pressure area, which would cause outside air to be sucked in through openings around the base of the tower. As this air is sucked in to fill the low-pressure void, it would drive rotor blades near the bottom of the tower.

The question with this device, as with all wind energy machines, is economics. With this design, you don't need a huge 300-foot rotor to extract substantial energy from the wind, but it is necessary to build a huge tower with a small rotor inside. Can the concept be made efficient enough to make the trade-off worthwhile? No one knows—yet.

For more wind machines, turn page

LOW-COST WINDMILLS

Two imaginative approaches to harnessing the wind focus on significantly lowering the cost of manufacturing the rotating parts of horizontal-axis wind devices:

Bearingless rotor

The more promising of the two is the bearingless-rotor concept being developed by United Technologies Research Center, East Hartford, Conn. The device, attached to a horizontal-axis wind turbine, is nothing more than a flexible rotor with a pendulum attached to each blade to help bend it to the desirable pitch. The inboard section of the blade (between the hub and the blade proper) is made of highly flexible carbon epoxy. This concept is now being tested on the tail rotors of two helicopters.

"If you arrange the geometry right, you get a very favorable pitch schedule," Dr. Pam Spierings of United Technologies told me. His company recently received a contract through Rocky Flats DOE's small-wind-systems program at Golden, Colo., to develop an eight-kilowatt machine using the bearingless rotor. Eliminating the need for mechanical pitch control could significantly reduce a wind turbine's cost.

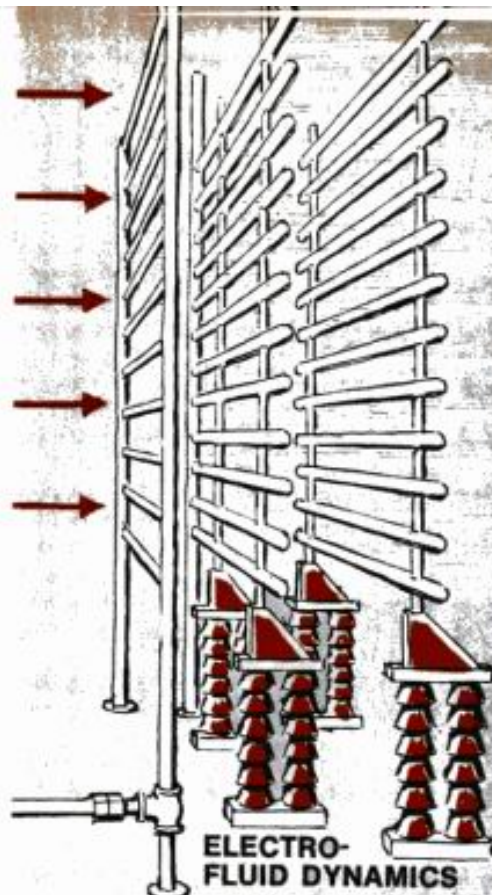
Bicycle wheel

The bicycle-wheel wind-energy concept seems to be one of those on which DOE gambles and sometimes loses. But losers have been known to come back into the race.

The original idea was conceived some three years ago by Tom Chalk of American Wind Turbine Co., based in Nebraska [PS, July '74]. Shortly thereafter, Oklahoma State University bought a 15-foot-diameter bicycle-wheel wind turbine from Chalk's company and proceeded to design a larger 30-foot-diameter model for testing. The resulting machine has 96 stainless-steel wire spokes, which support 48 airfoils, each about 10 feet long. The machine served its purpose.

Discussing the outcome, Dr. Dennis McLaughlin of OSU said, "We built this big thing and we ran some tests on it. The goals of our work were to design, construct, and evaluate. From my point of view after we were done, I was convinced that the scheme was not a viable design."

As a result, the machine was slated for dismantling within a few weeks of this writing. One big problem: The device presents a lot of rotor to the wind, compared with the two or three blades of a conventional rotor, making high-wind protection difficult.



FAR-OUT WINDMILLS

This category of designs consists of the most purely research-oriented of the ideas being funded by DOE.

Electrofluid dynamic

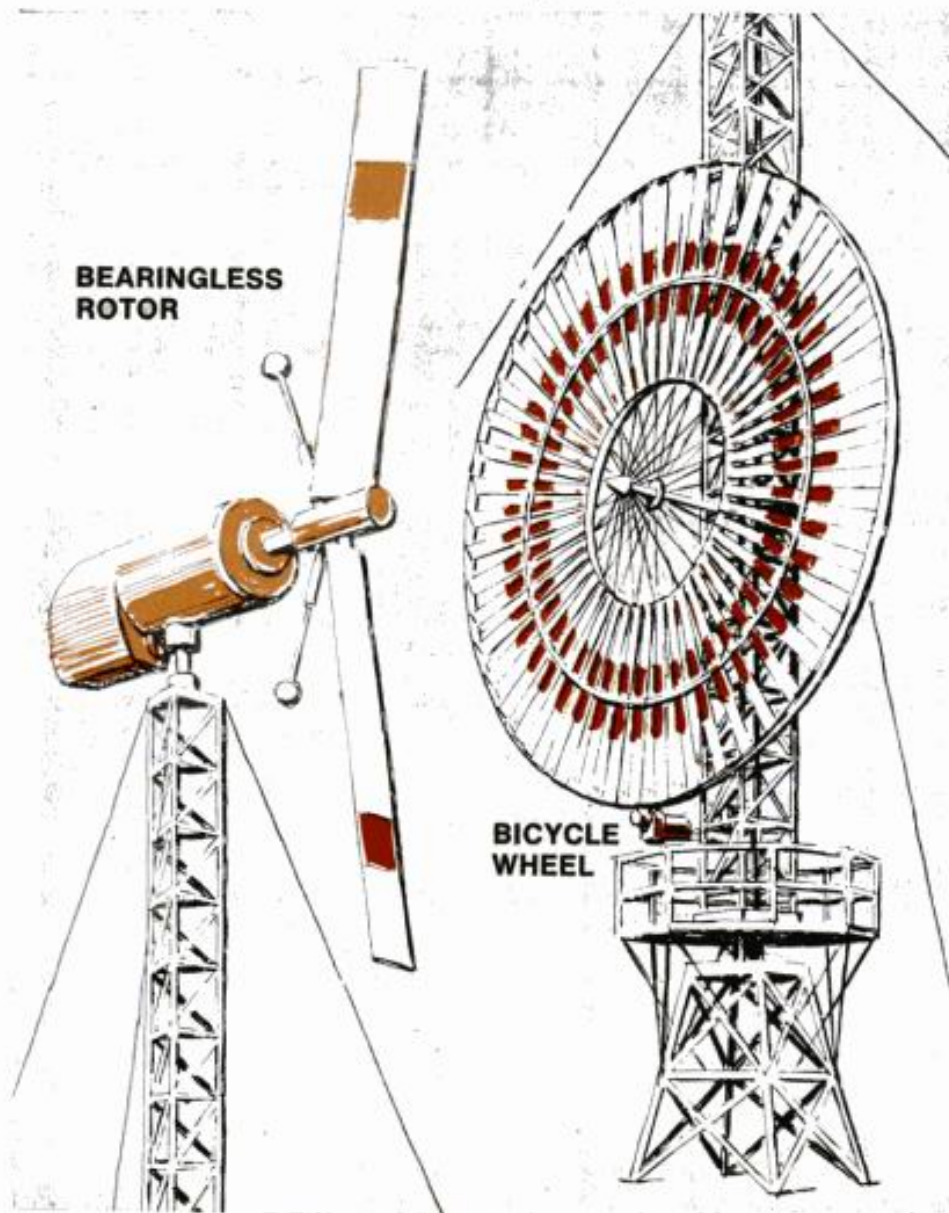
One of the most theoretical of the far-out concepts is the electrofluid-dynamic (EFD) category, with two devices being developed under separate DOE contracts. A fascinating element of this concept is that it has no moving parts.

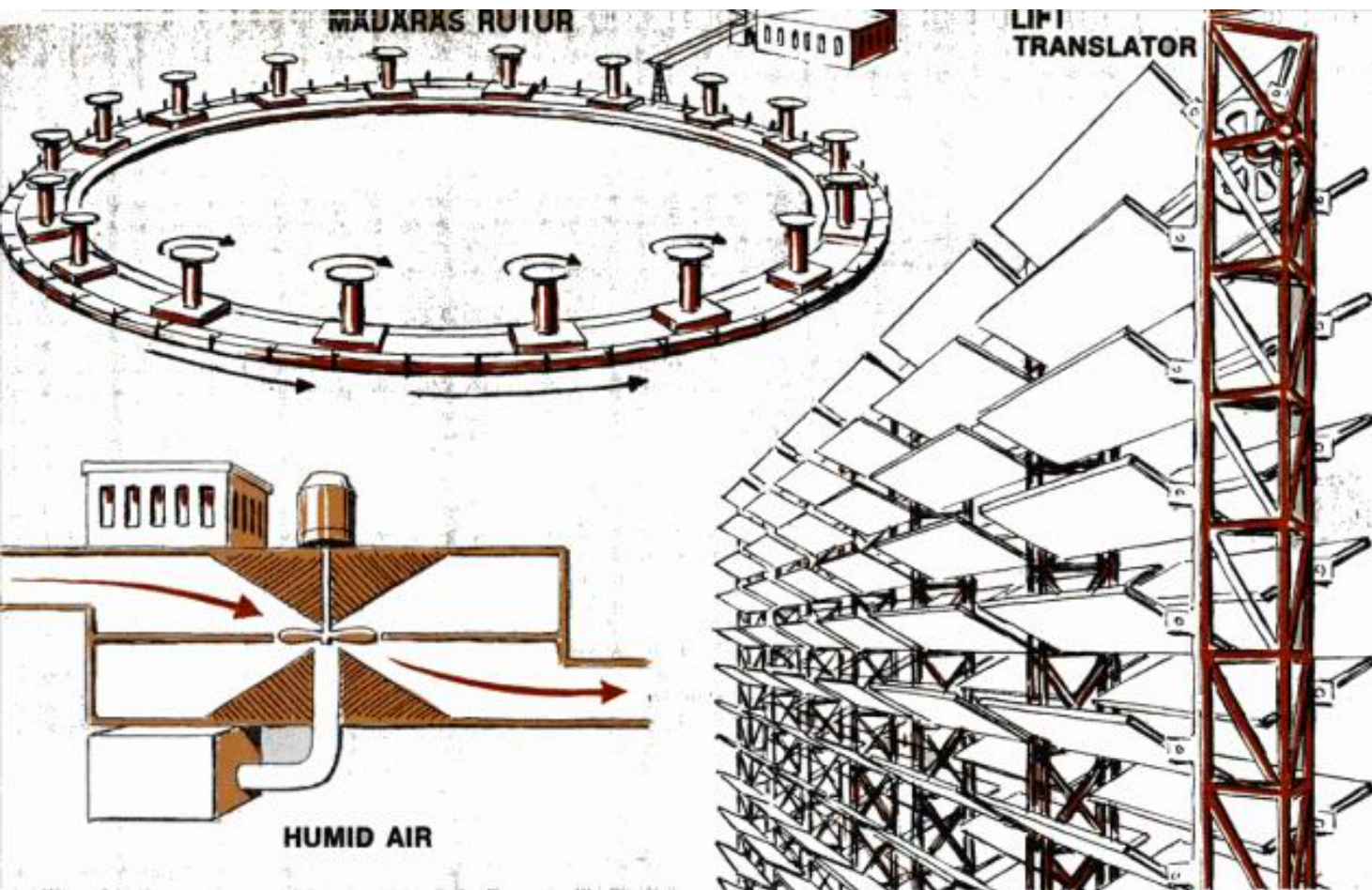
How does one capture energy from the wind with no moving parts? Easy, or so it seems. Making the concept work in the real world is another matter. In essence, what the EFD device does is reproduce nature's way of creating lightning in a thunderstorm.

"The charged raindrops accumulate in a cloud and form an electric field. When it becomes strong enough you get lightning. What I did was bottle this whole phenomenon," said Alvin Marks, president of Marks Polarized Corp., Whitestone, N.Y., the developer of one EFD system. The other is being worked on by Dr. John Minardi of the University of Dayton (Ohio).

Each of the researchers has built a wind-tunnel test model. Marks has produced one-tenth of a watt with his apparatus, which he figures would come to about 450 watts in a 22-mph wind for each square meter of device. While their machines differ in design, their methods of producing power through EFD are basically the same.

The idea is to have the wind blow water droplets through a highly charged grid, thereby causing the droplets to become charged. The wind would then blow these particles toward





another charged grid. The mechanical energy of the wind does work in overcoming electrostatic repulsion, and the energy is translated into electrical current.

Marks explains it this way: "What we do is inject charged droplets into the windstream. The charge is eventually carried by the wind to the electrical ground, but it has to climb a potential hill to get to ground." The load is placed between the collector grid and the ground.

Work now being done by both Dr. Minardi and Marks is aimed at developing methods of producing charged water droplets. One method being investigated by the Ohio researcher is to use liquid hydrogen for cooling moist air to produce small liquid droplets that can then be passed through a corona discharge. Marks is looking into using small water jets which would be shot through an electrical field.

Humid air

As have the EFD people, a group of researchers at the South Dakota School of Mines and Technology, Rapid City, have taken their cue from nature for developing a wind-energy device.

The research done by the team, headed by Dr. Thomas Oliver, revolves around the fact that about one-third of the solar energy that reaches the surface of the earth goes into evaporating moisture. So far, Dr. Oliver has been through a series of designs that would capture this energy, but there have been drawbacks.

There was the original natural-draft tower in which humid air would be brought in at the bottom. The wet air, being lighter than dry air, would rise

and would expand, causing its temperature to drop. The cooler air would give off water, and the latent heat in the humid air would be given off to the now drier air. The warmer air would have increased buoyancy and would continue to rise up the tower, passing a wind turbine on its way out. The problem with this idea is that it would require a tower of some 10,000 feet.

The next idea was to build a mechanized expansion-compression cycle to boost this natural process and reduce the height of the tower. But some of these designs involved expansion-compression machines that used too much energy.

The approach being considered now is a vortex-flow device in which one machine would accomplish both the expansion and compression of the air. Humid air would enter on the upper end of an expansion chamber. The air spirals to a low-pressure area where it could be cooled by a water spray, then go on to a compression chamber. A rotor could be placed in the flow path to extract power.

Madaras rotor

A train to nowhere, which its developers hope will lead us to energy self-sufficiency, is the key to the Madaras rotor power plant. Named after Julius Madaras, who invented the concept in the 1920's, this system consists of a circular track with a train of flatcars, each with one revolving vertical cylinder mounted on it. An electric motor on each car spins the cylinder like a top. The interaction of the wind with the turning cylinder propels the car down the track. Generators attached to the wheels of the cars produce power, which is taken off by a

third rail operating like a conventional electric train, but in reverse.

A group of utilities supported the early development of the Madaras concept to the point that an experimental rotor was built on a fixed platform in Burlington, N.J., in 1933, but hard times and cheap fuel killed the project. It was resurrected three years ago by Dale Whitford of the University of Dayton, and about a year ago was accepted into DOE's advanced-concepts program.

Lift translator

The lift translator [PS, Feb.] developed by Dr. Daniel Schneider, a physician based in Irving, Tex., can be likened to a cyclogyro vertical-axis wind machine laid on its side. This idea can be adapted to use either wind or hydro power. Indeed, most of the DOE funding it now receives is to develop a water-actuated system.

For wind use, the apparatus consists of a series of aircraft-wing-like airfoils attached to an endless belt. The foils on one side of the belt are pushed up by the wind, while those on the opposite side are also contributing to energy production as they are pushed down by the wind. Because this machine can be actuated from a fixed position by winds coming from a wide range of directions, it needs no yaw control. It also is not limited to size as are wind machines with conventional rotor blades, and it can operate in a wide range of wind speeds.

A 45-foot-high working model built at the University of Texas at Dallas proved the viability of the concept. It ran for nine months and generated up to 15 kilowatts of power. The question now is real-world economics. □

Sea-Floor Rover— Master of All Trades Underwater

BY HERBERT SHULDINER

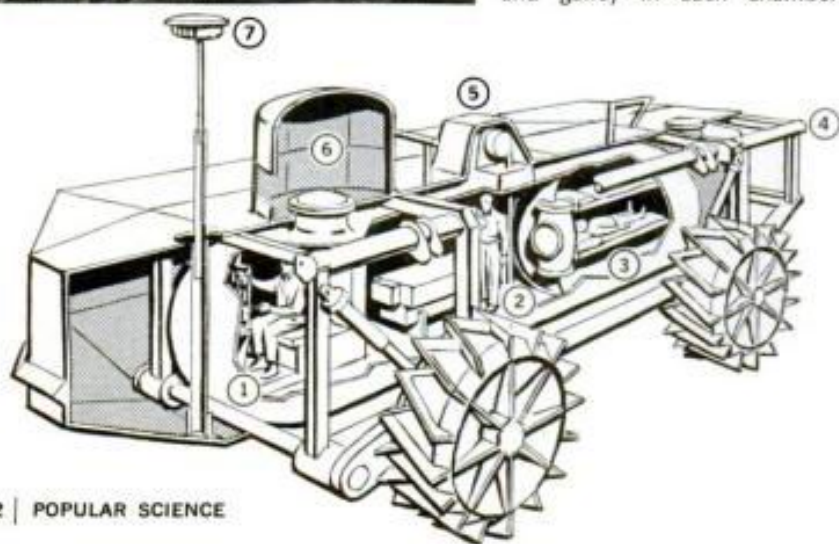
A giant undersea tractor that can roam the ocean floor at depths as great as 600 feet is about to provide a new dimension in oceanographic exploration. This sea-floor rover—called the Sea Bed Vehicle, or SBV, by its builders, Cammel Laird Ltd. of Birkenhead, England—is slated to undergo its first sea trials in December. It can ride over the soft, uneven ocean floor on its four huge wheels, giving aquanauts the kind of support and freedom they've never had before, for jobs like ocean-floor drilling, cable laying, mining, or as a base for diving over extended periods. Unlike free-swimming, deep-diving vehicles, the SBV is lowered by a support ship at the end of a cable which also supplies the umbilical links to the mother ship for power and communication.

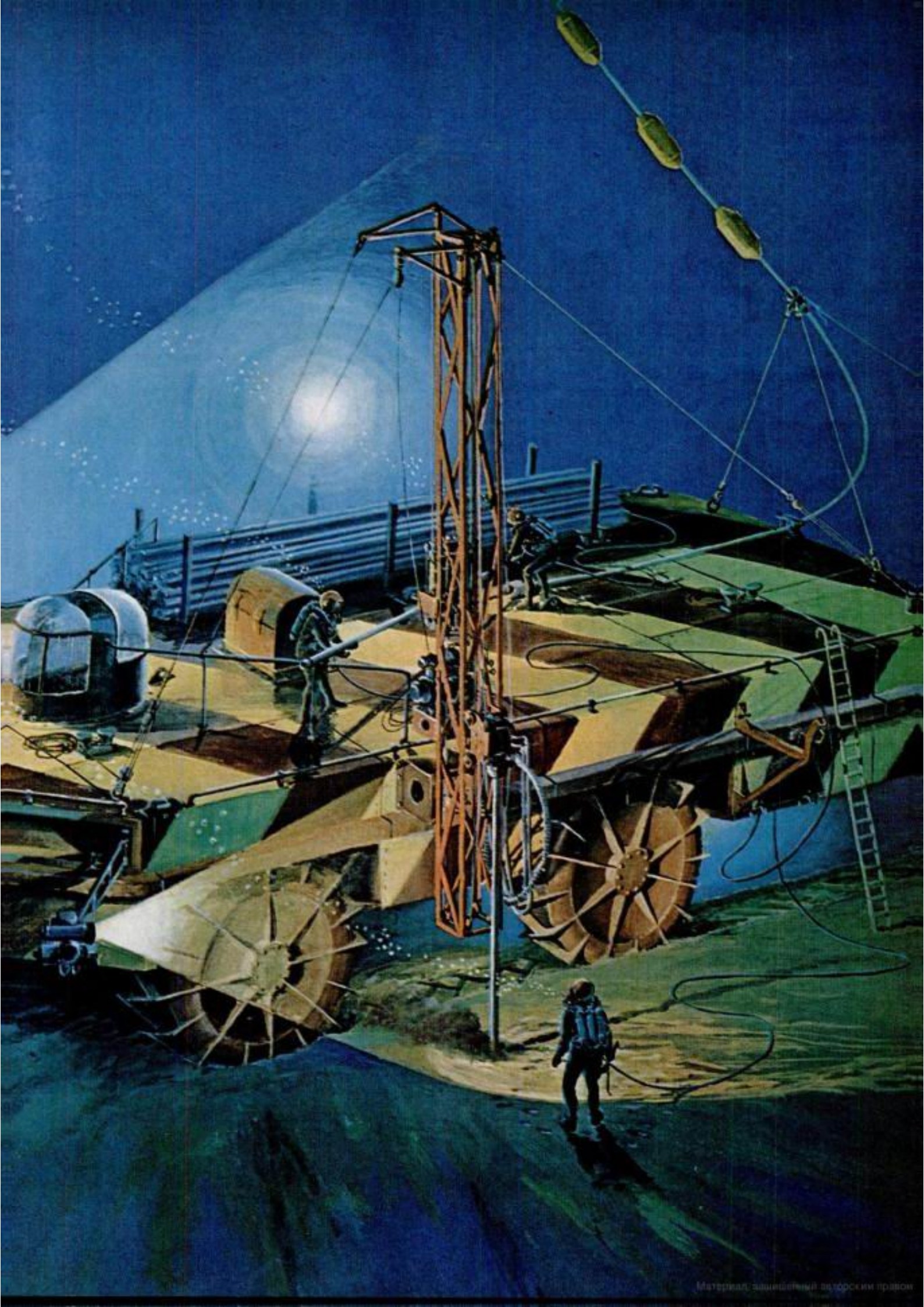
Once this 60-ton vehicle reaches the ocean floor, however, it is self-powered, with a direct-drive motor in each wheel. A dead-reckoning navigation system, two TV cameras, and a high-resolution sonar help the operator guide the rover. It can carry two persons in the control cabin, plus three divers, and support them for five days before resurfacing. Top speed? One-and-a-half knots.

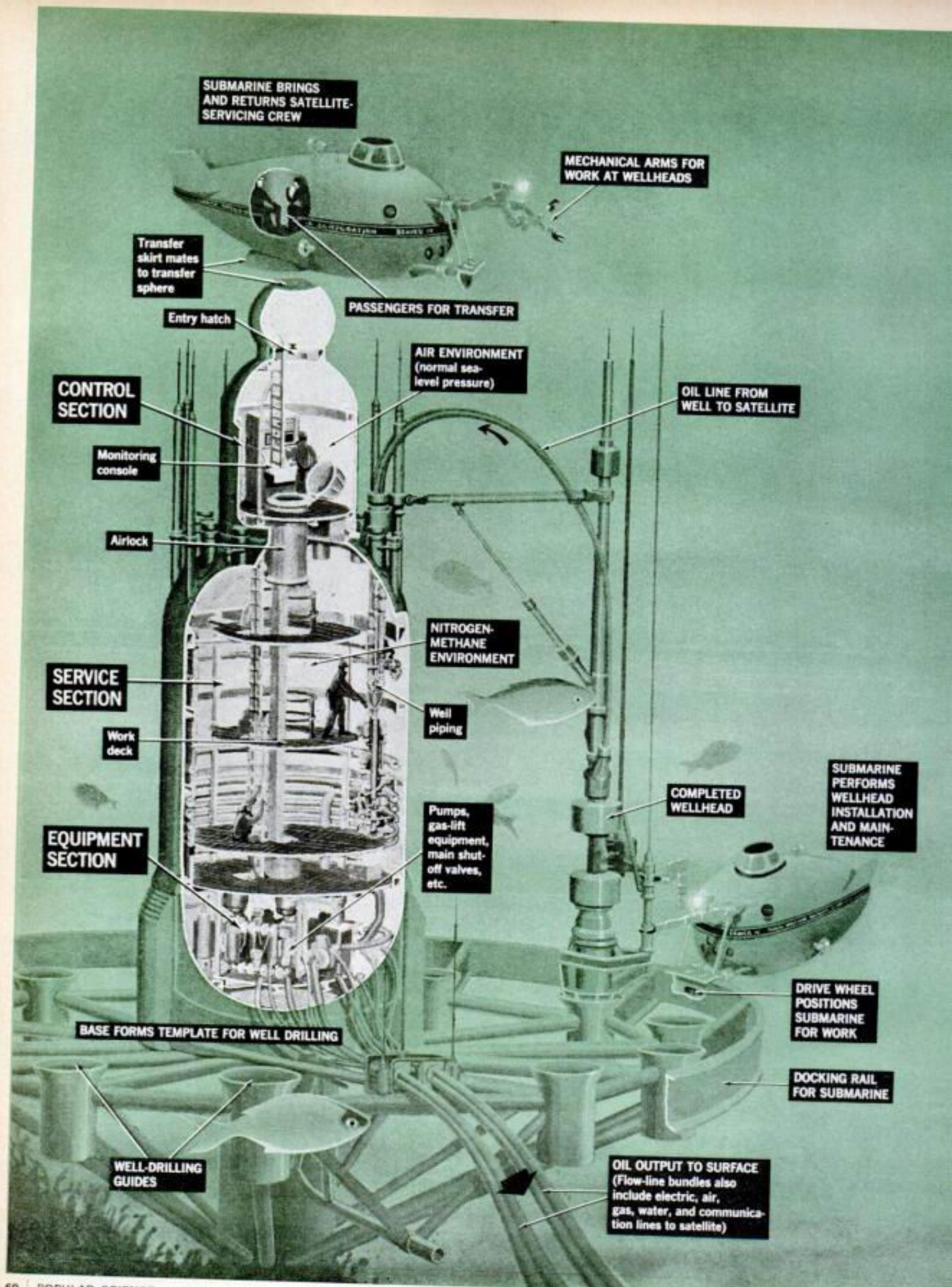


Salvaging a wrecked ship (left) will be one of the jobs aquanauts will handle from the Sea Bed Vehicle. Undersea rover will be tested at end of this year

Inside look at the Sea Bed Vehicle below shows: (1) control room; (2) isobaric chamber; (3) hyperbaric chamber; (4) exterior frame; (5) winch housing; (6) free flooding observation cockpit; (7) sonar. The rover is 19 feet wide, stands slightly over 16 feet high with wheels extended for ocean-floor travel. The wheels are eight feet tall, three feet wide. Payload is 9,000 pounds. Afloat, it has a seven-foot draft, 101,000-pound displacement. There's a toilet and galley in each chamber







Underwater Satellites to Tap Offshore Oil

By ALDEN P. ARMAGNAC

Inhabitable ocean-floor "satellites" tended by submarines will tap undersea oil beyond the reach of divers, at depths down to a mile or more, in a joint program of Mobil Oil Corp. and North American Rockwell Corp.

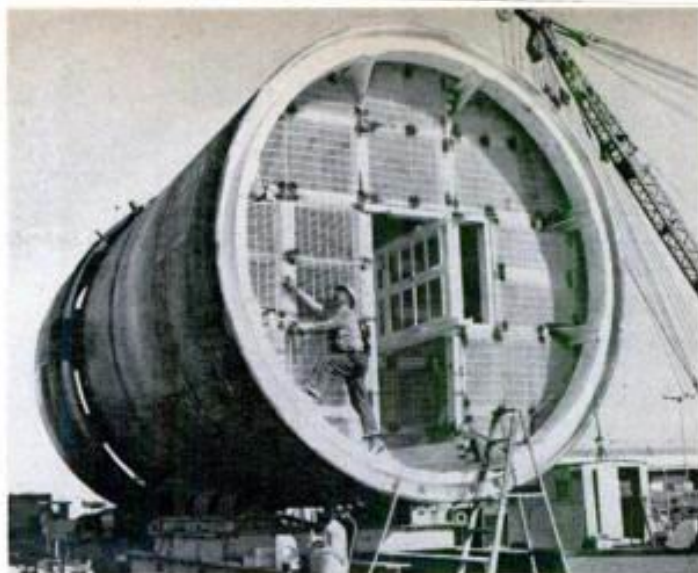
Each cylindrical 50-foot-tall satellite will be an oil-production station to control and maintain up to 16 oil wells drilled through guides in its base—and to collect and deliver their output to the surface.

Although automatic in operation, a satellite will be serviced and kept in repair by a crew's periodic visits. Its upper "control" section contains air for breathing. Lower sections, guarded against fire by a non-reactive nitrogen-methane atmosphere, can be entered by wearing masks with air hoses or portable air tanks.

A five-man submarine such as NAR's Beaver Mark IV will dock atop the satellite to deliver and return a crew. Mechanical arms of the submarine will assemble well-heads and manipulate valves when the craft has engaged a docking rail around the satellite's base. **TE**

Fifty-foot-tall satellite with crew aboard is depicted on sea floor off West Coast in cutaway view on opposite page. Composite picture includes two views of satellite-tending submarine, shown (top) docking to satellite for crew transfer, and (bottom) using mechanical hands to assemble first of up to 16 wellheads encircling satellite.

Complete satellite oil-production system can take one of two forms: At left, satellites as far as 1,000 feet below surface deliver oil to barge via fixed platform (in water no deeper than 600 feet),



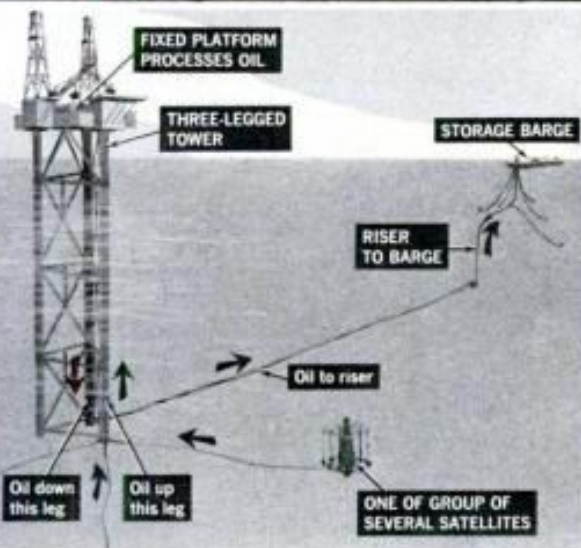
Successful dry-land tests of this full-scale portion of a satellite at Long Beach, Calif., point to possibility of an actual deep-sea installation of system within the next year or two.



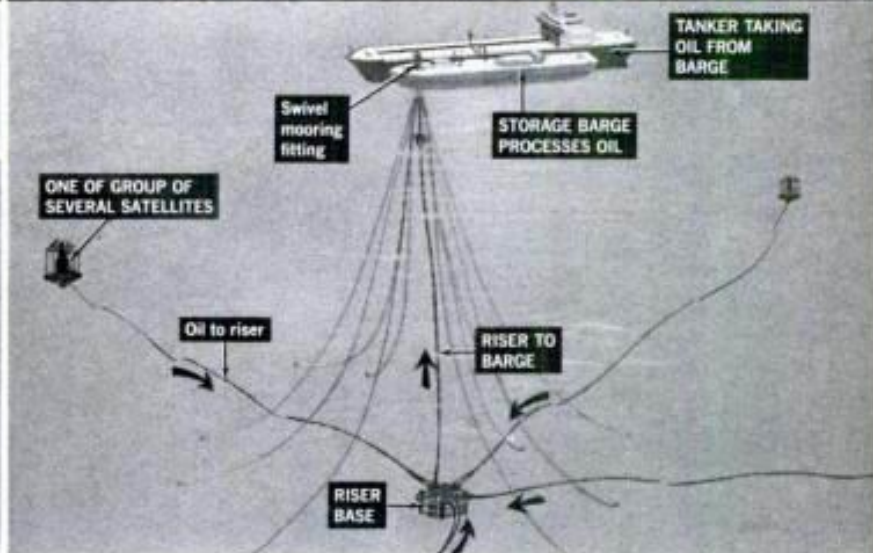
Satellite will be tended by submarine like Beaver Mark IV, pictured above with diver emerging under water. Through hatch of docked submarine, crew would enter satellite without getting wet.

which processes it on way. At right, oil from satellites at maximum 6,000-foot depth goes direct to processing plant on barge. Surface ship swings with seas on swivel mooring.

EARLY SATELLITE SYSTEM — for depths to 1,000 ft.



ULTIMATE SATELLITE SYSTEM — for depths to 6,000 ft.





A 1/10 scale model of South Pole Station was erected last year to test design's resistance to snow buildup. Tests indicate it should survive 10-15 years.

Our New Antarctic Outpost:

Big Bubble Atop the South Pole

Take a top-of-the-world idea like the igloo, update it in aluminum, and you've got a bottom-of-the-world center for science

By MARK WALKER ILLUSTRATION BY FRED WOLFF

The South Pole, 90 degrees south, the absolute bottom of our Earth, where time slows to a day and a night per year . . . A barren desert plateau, with nearly two solid miles of ice underfoot. The air is thin and colder than dry ice. Wind-whipped snow slashes at unprotected skin and reduces visibility to zero.

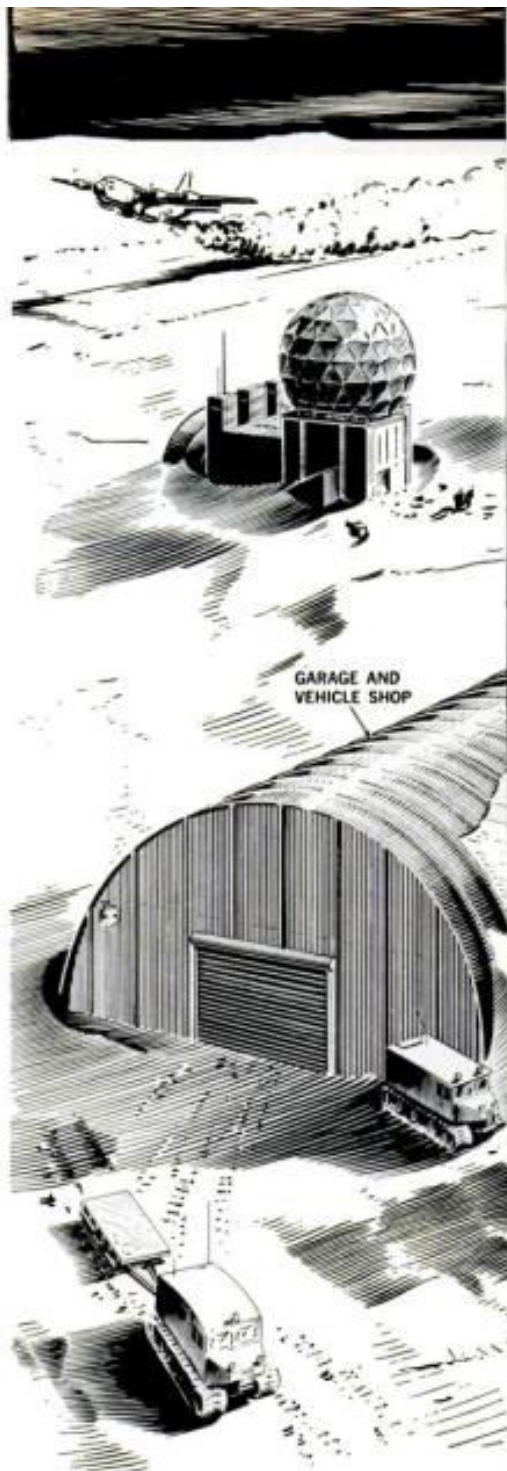
English-explorer Robert Scott, reaching the pole 30 days after its discoverer, Roald Amundsen, had left, wrote in his diary, "My God, this is an awful place!" Two months later, he and

all his party had died of exposure and starvation making the return trip.

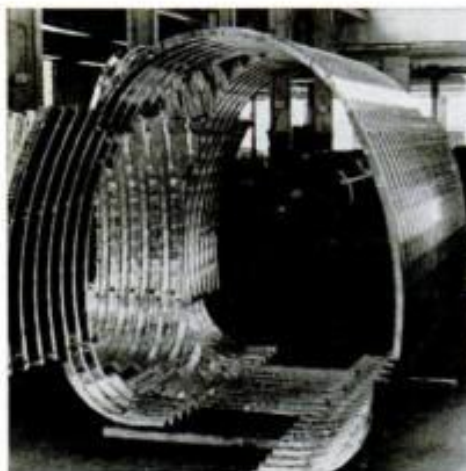
Yes, the south pole is an awful place, an especially awful place to build a city—the job assigned to the Navy's Construction Battalion (CB-201).

When summer comes to the pole in November, the Seabees will head south to begin construction of a new scientific station. By next year, a geodesic dome 164 feet across and 50 feet high will cover the pole like a giant bubble. Inside? A library, post office, science

Continued

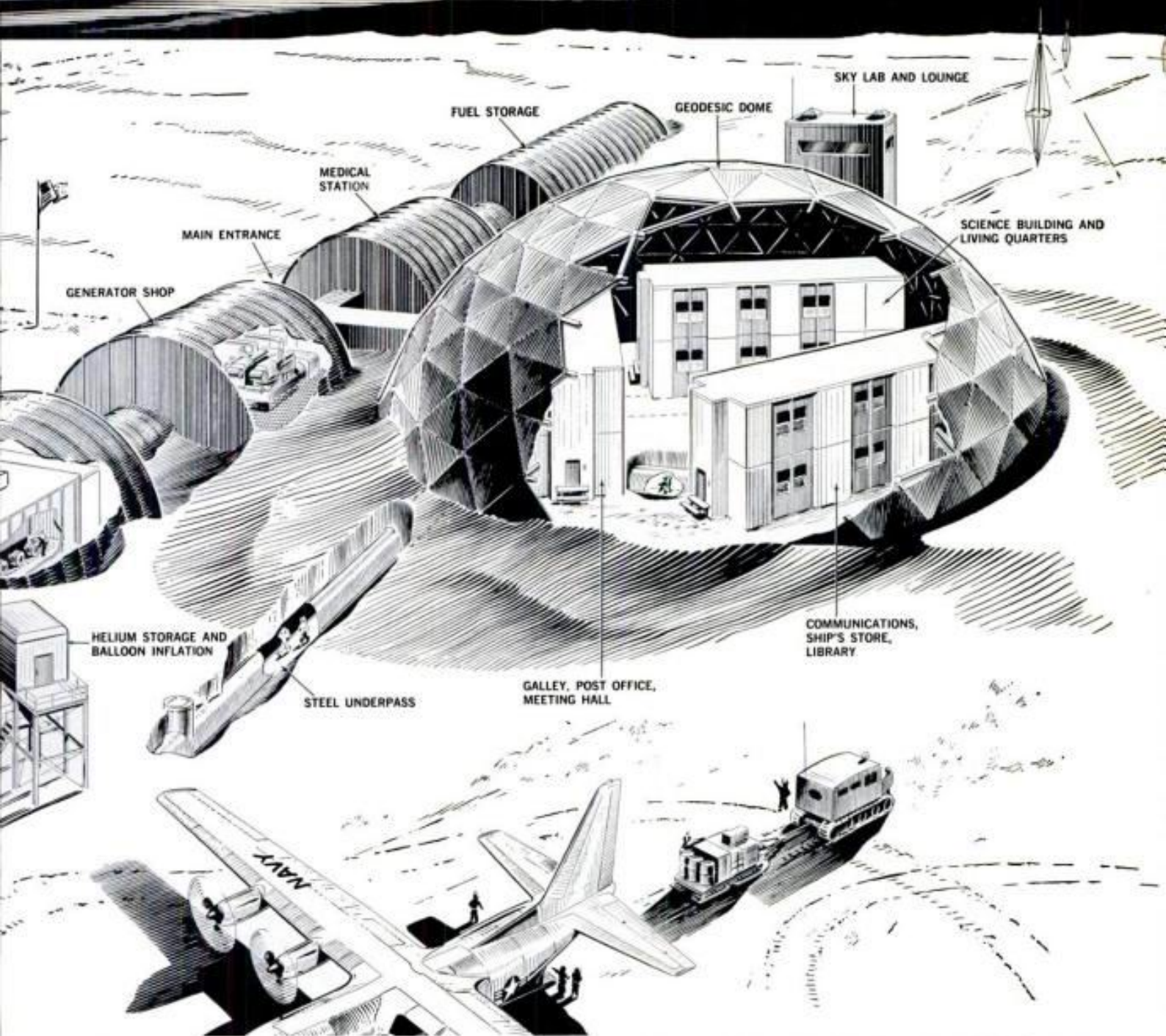


Polar home for Operation Deep Freeze is



Test assembly of components for the site helps to assure a trouble-free fit under the difficult conditions at the pole. Above, at left, is a T-junction for corrugated steel underpass,

made by Republic Steel; at center, the Wonder Arch, by Jones & Laughlin; at right, aluminum framework of the geodesic dome, made by Temcor of Torrance, Calif.



enclosed under an aluminum igloo and steel "Quonset huts" for protection—not from cold, but from the weight of snow.



Peter "Snow Miller" rotary plow prepared the foundation for the dome by digging eight-foot-deep trenches, filling them with pulverized snow, packed hard as concrete.



Wonder Arch, a main building block for the new station, was proven at the old station where it was used to protect buildings threatened by the crush of drifting snow.

ALCOA

How to find a needle in the world's darkest haystacks—the deep oceans

By ARTHUR FISHER

ILLUSTRATIONS BY PIERRE MION

Suppose you lost something valuable in the depths of the sea. How would you go about getting it back?

The problem has proved of nightmare difficulty in several recent search and recovery missions, for objects ranging from an H-bomb off the coast of Spain to a nuclear sub in more than 8,000 feet of water.

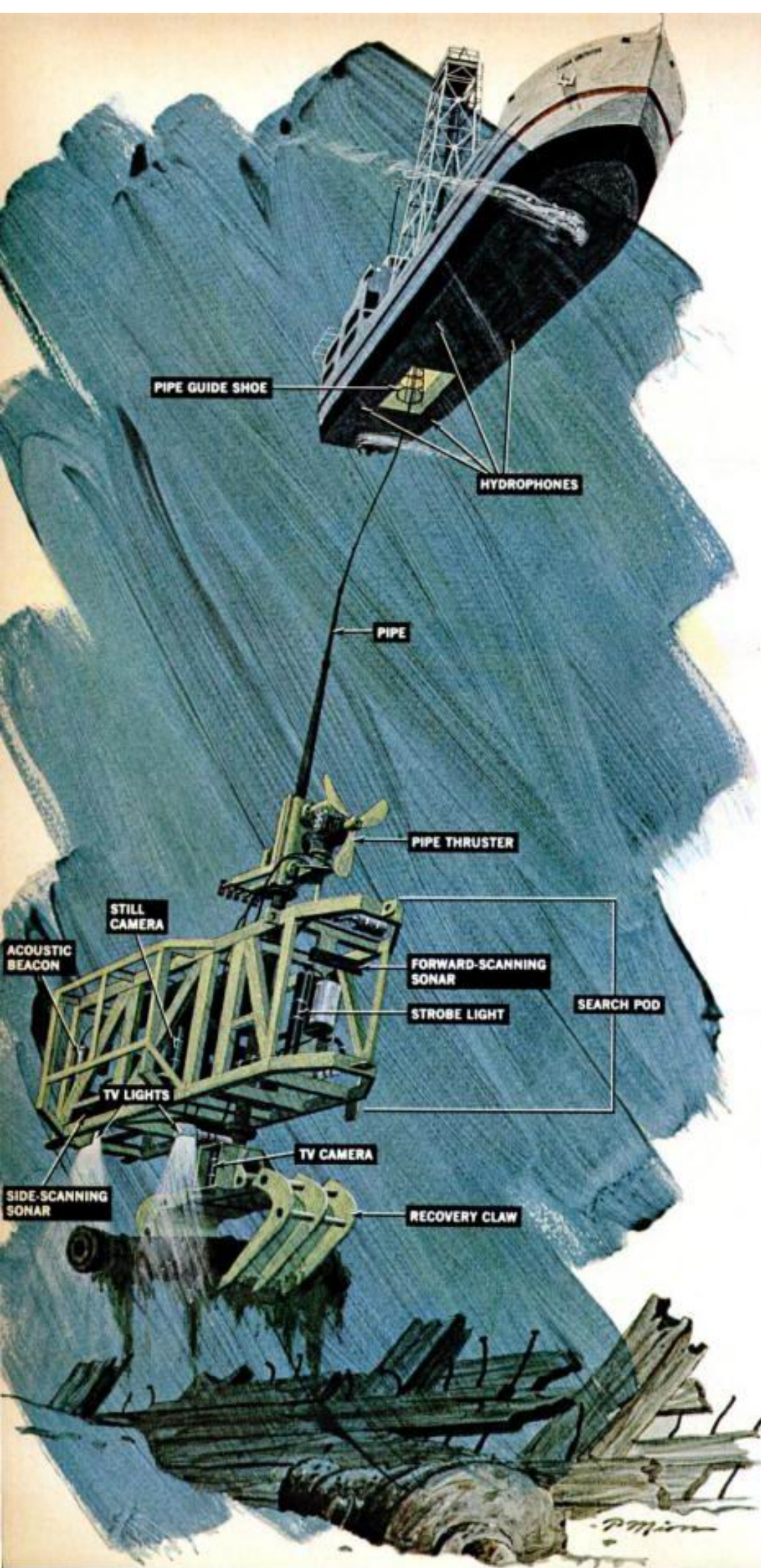
Most such missions require the coordinated labors of complex, expensive, and balky equipment, including, besides surface ships, manned submersibles, remote-controlled underwater manipulators, and towed devices containing detectors such as sonar, TV and still cameras, and magnetometers.

Now there is a remarkable new ship that integrates all of the search and recovery functions in one glittering, all-aluminum package. The Alcoa Seaprobe can recover 200-ton payloads from 6,000 feet below the surface of the water. And there's a big plus: It will also search, core, drill, and sample the ocean bottom in water depths to 18,000 feet, making it a powerful scientific research tool in the assault on "inner space."

Here are some of the engineering features that combine to make this do-everything ship the most advanced oceanographic vessel afloat:

- The 243-foot ship is constructed completely of a new aluminum alloy with high resistance to sea-water corrosion. The Seaprobe is owned and operated by Ocean Search, Inc., a subsidiary of Aluminum Company of America, and one of Alcoa's objectives was to prove that a large, all-aluminum ship was practical to build.

- The Seaprobe can hover above a given spot on the ocean floor with almost the precise control of a helicopter. It can maintain its heading regardless of sea conditions, move through the water sideways at any angle, and spin around in a circle her



SEAPROBE —

New Do-Everything Research Ship

own length. Precise dynamic positioning is made possible by the two Voith-Schneider cycloidal propulsion units, one forward and one aft, each with its own diesel-electric drive system. The cycloidal units also provide go-power for normal cruising—at about 10 knots. The ship's position can be controlled both from the pilot house and from an operations center whose TV screens display everything that's happening on the bottom. To get an accurate fix on the desired spot on the bottom, the ship's hydrophones pick up signals beeped out by acoustic beacons. And the ship can navigate ultraprecisely with radar, shore-based radio location, and worldwide satellite systems.

• The business end of the Seaprobe's engineering comes at the bottom of a string of steel drilling pipes—60-foot lengths threaded together to reach the desired depth. The string is semirigid. It's stiff enough so that the

equipment at its end can be maneuvered horizontally by a thruster powered by water pumped down through the pipe. This gives accurate positioning of sensor packages, recovery claws, or boring tools. Yet the string "gives" enough so it won't snap even when the ship is steaming forward at four knots. The 4½-inch pipe's tensile strength, matched to the heavy-duty draw works and 132-foot derrick, enable the Seaprobe to lift up to 200 tons from 6,000 feet.

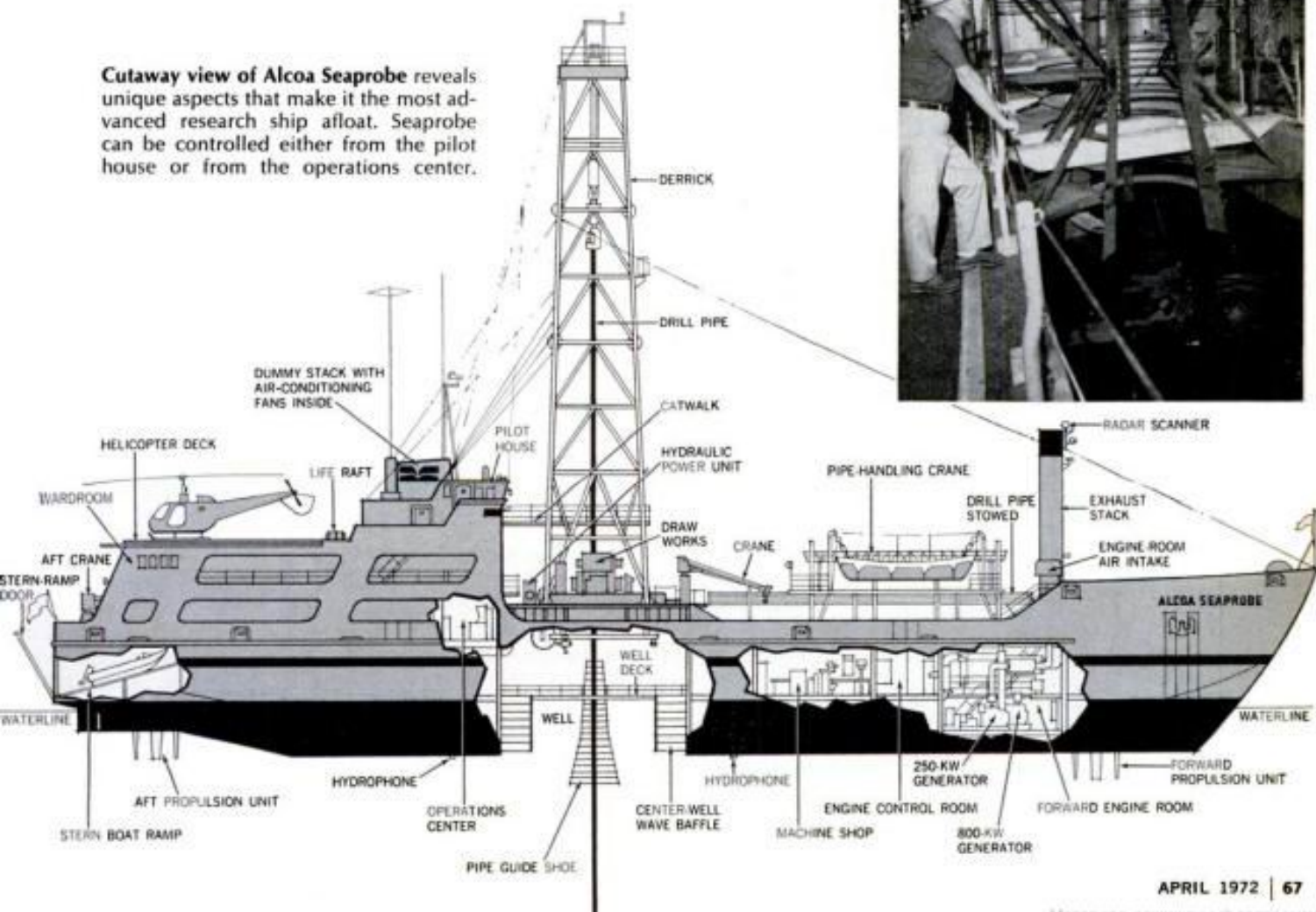
• A large (12-by-36-foot) center well directly beneath the derrick pierces right through the Seaprobe's hull. This allows large, multi-ton objects to be lifted straight into the ship and then be stowed safely in the 50-by-60-foot well deck working space. In fact, there are plans to try launching and retrieving the Johnson-Sea-Link, a research submersible ["See-All-Around Bubble Sub," PS, Sept. '71], through the Seaprobe's well. **ES**



Cycloidal propeller units (above), installed fore and aft, provide power for ocean transits and dynamic positioning. Pipe guide shoe (below) centers pipe in well.



Cutaway view of Alcoa Seaprobe reveals unique aspects that make it the most advanced research ship afloat. Seaprobe can be controlled either from the pilot house or from the operations center.



NOVEMBER 1973 60 CENTS

Popular Science

THE **What's New** MAGAZINE

**AIR BAGS ARE HERE
FOR SOME '74 CARS**
What You Should Know
About Them Before
You Buy Your Next Car

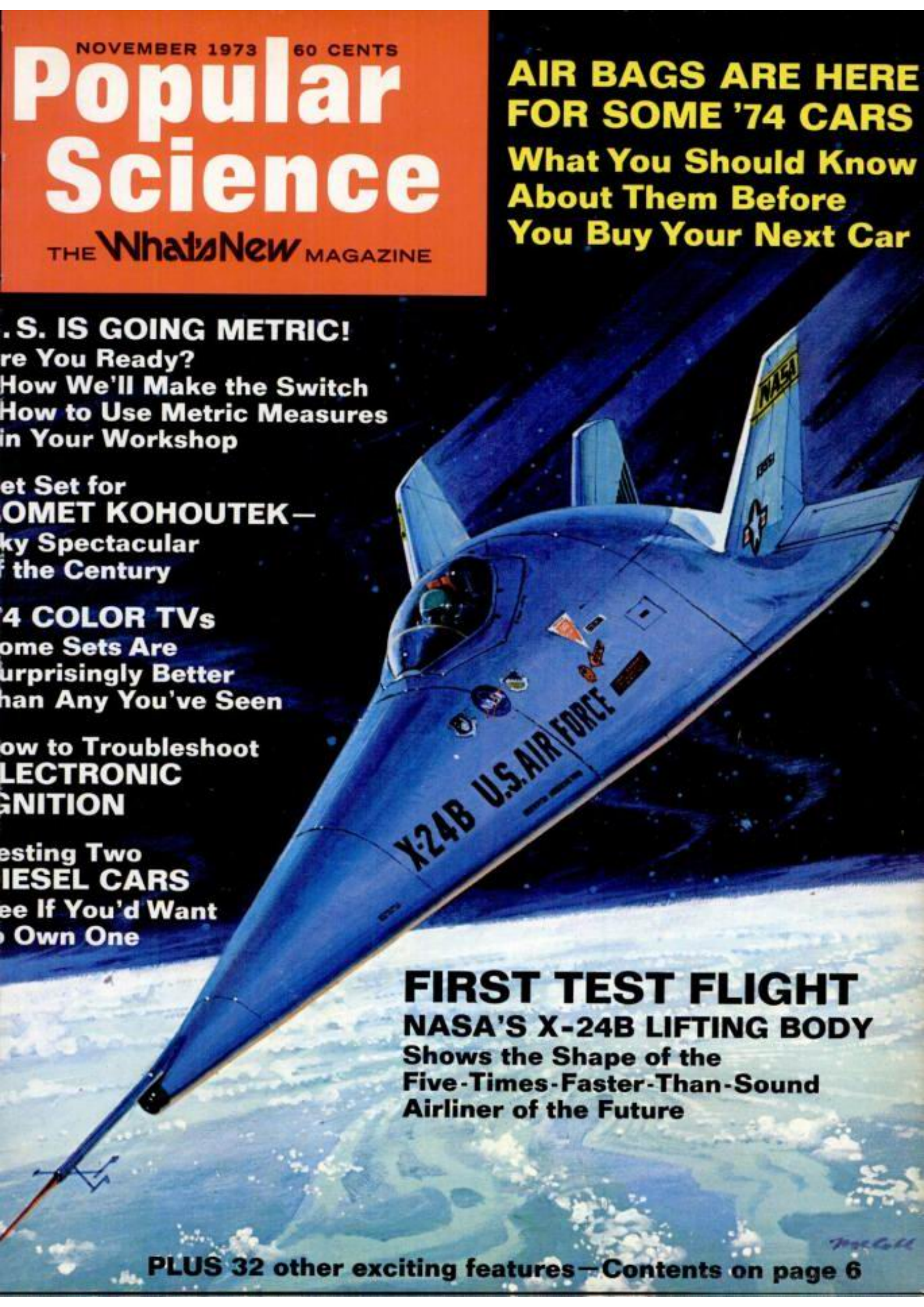
U.S. IS GOING METRIC!
Are You Ready?
How We'll Make the Switch
How to Use Metric Measures
in Your Workshop

Get Set for
COMET KOHOUTEK—
A Truly Spectacular
of the Century

4 COLOR TVs
Some Sets Are
Surprisingly Better
than Any You've Seen

How to Troubleshoot
**ELECTRONIC
IGNITION**

Testing Two
DIESEL CARS
See If You'd Want
to Own One



FIRST TEST FLIGHT
NASA'S X-24B LIFTING BODY
Shows the Shape of the
Five-Times-Faster-Than-Sound
Airliner of the Future

PLUS 32 other exciting features—Contents on page 6



Dropped like pointed rock from its mother ship, X-24B begins flight.



Test pilot John Manke explains how upper and lower tail flaps move independently to stabilize plane, slow its flight, or change trim. Rocket motor exhausts fit snugly between the tail flaps.

Flying NASA's X-24B Lifting Body

Flying at hypersonic speeds in near space and at slow speeds for landing is a problem for one aircraft. This strange shape can do both

By **BEN KOCIVAR** / *PS Consulting Editor, Flying*

Shortly after dawn at the NASA Flight Research Center at Edwards, Calif., PS cover artist Bob McCall and I hold our breath as we watch the first test drop of a new breed of lifting body. Down it comes off the wing of a B-52 at 40,000 feet. Within four minutes, dropping in an 18,000-feet-per-minute dive, the craft flares to a nose-high landing and

then rolls 7000 feet to a standstill.

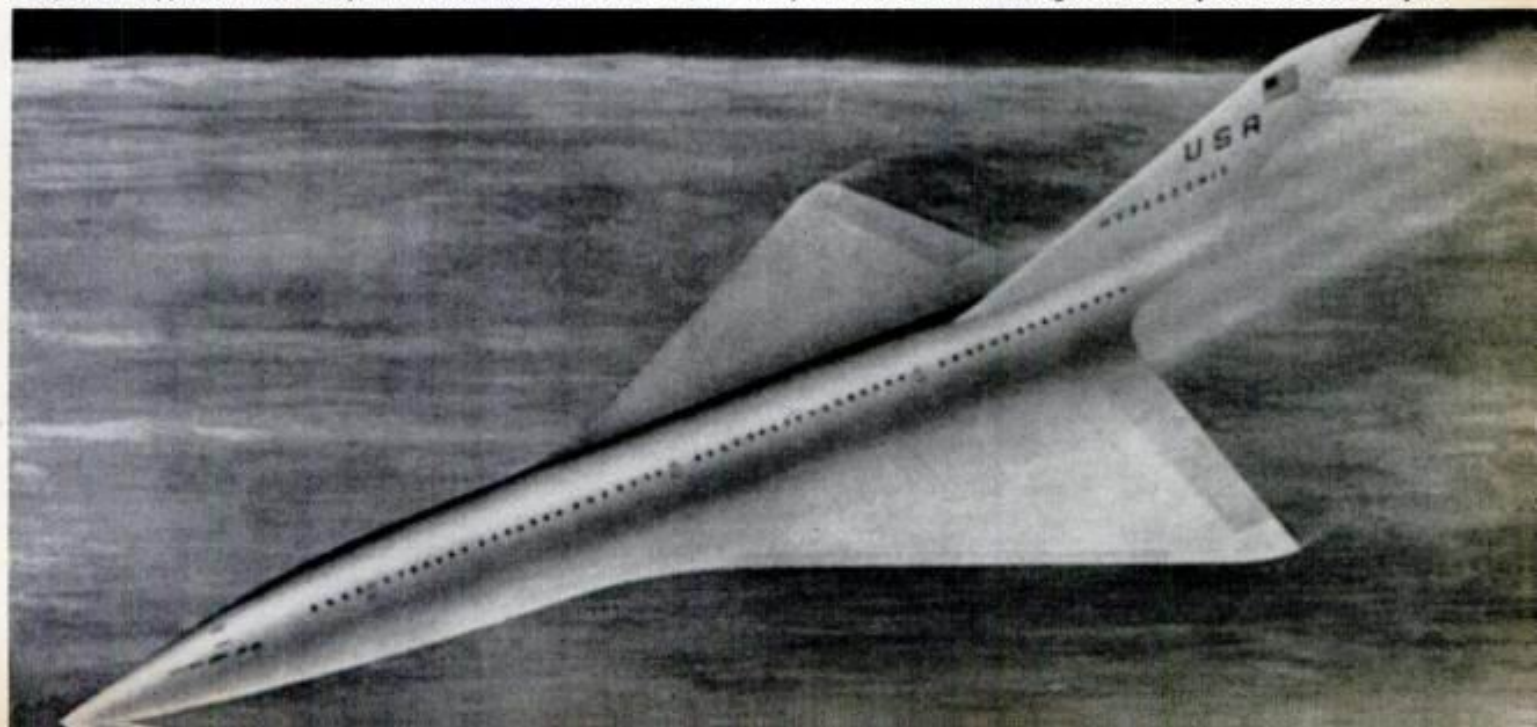
Your mind tells you this ship cannot help but fly like a rock. It has all the streamlined beauty of a pointed potato. It glides like the flying flatiron that it resembles in profile. Yet, this triple-tailed, 37-foot-long beast—called the X-24B—is the wild shape of future high-perfor-

Continued



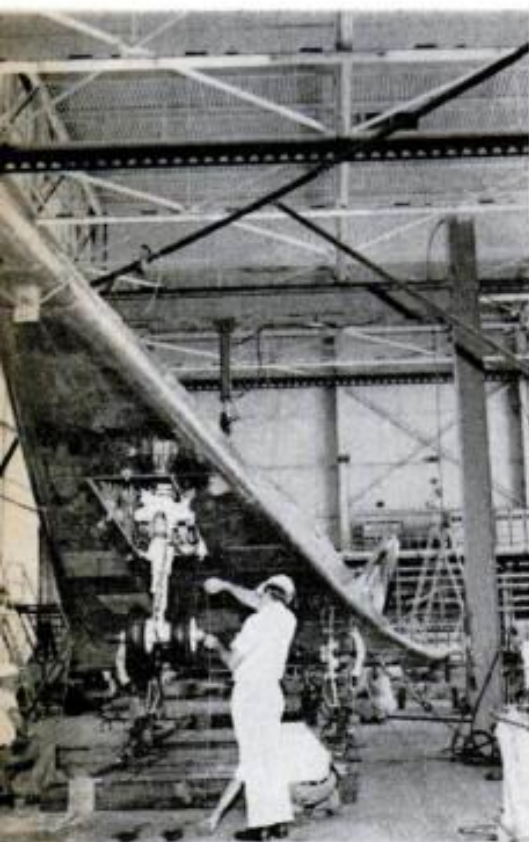
Cockpit is surprisingly roomy, and panel appears less complex than most jets. Author Kocivar gets checkout from Manke after the first test drop.

Proposed hypersonic transport looks like Concorde SST—only it has smaller wing. Cruise speed is 3500 mph.



"Maximum speed and altitude will be about 1000 mph and 70,000 feet"

mance aircraft that you may fly in. The key to it all is the lifting body—a shape that will operate in outer space as well as in the Earth's atmosphere. It's hard to design a craft to do both. The rounded blob



Ground tests before first gliding flight included spinning the nose wheel to touchdown speeds, then dropping the plane from this extremely nose-high position to measure the hefty loads on the wheel at landing impact.

shape of the first lifting bodies was designed to spread the heat load to keep the ship from melting. Although it was a good shape for reentry vehicles, it was a lousy one for flight at lower landing speeds, because it was aerodynamically uncontrollable. Gradually, the more pointed shape was developed in research tunnels.

Computerized stability. Richard Brackeen, program manager for Martin-Marietta, the company that built the X-24B, says the shape is like a VW at speed, a flat-flying wing that has unpredictable control problems because it is so stubby. The pilot can fly it only because he is backed up by computerized controls (called "stability augmentation") that make thousands of small lightning-like corrections to keep it from tumbling out of control. (He does not feel this process in his stick forces, and it does not interfere with directional changes he makes with his controls.)

You may get to fly in a lifting body, too. One NASA expert told me that by 1990 big 3500-mph planes with that strange profile could take off independently with 250 passengers at a time on two-hour hops between Los Angeles and London.

And the Air Force likes the design. They want it for a new hypersonic fighter-interceptor.

New lifting bodies like the space shuttle will be able to make landings at airports and have a choice of landing sites. (The old ones had to be slowed by parachutes and recovered in ocean splashdowns.) But like other manned space vehicles, they must

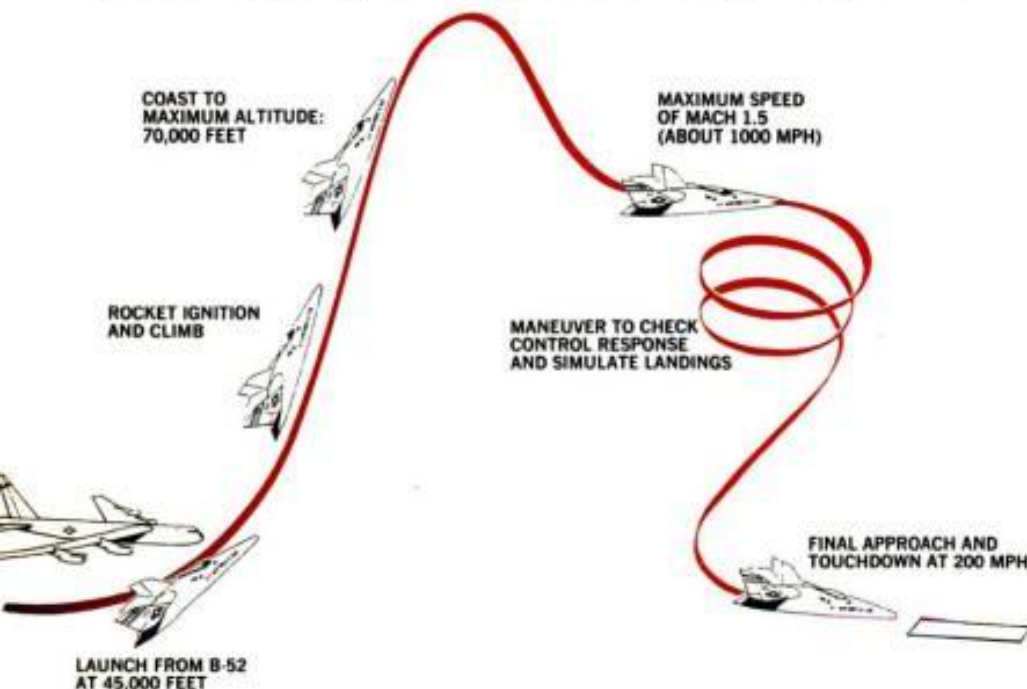
have a system for dissipating the searing heat when they hit the atmosphere at several thousand miles per hour. Hypersonic airliners that will operate in near space at about 100,000 feet will also have serious heat problems. Flying wider cross-ranges means spending more time at high speed in the atmosphere than ballistic-type space vehicles do. Result: more heat from prolonged air friction.

How to handle heat? We're familiar with the ablative materials used to dissipate heat by letting the air burn away the outer skin of space capsules as they reenter the atmosphere. Titanium can withstand high temperatures. There are new honeycomb metal structures that insulate the inner structure. Yet all of these take up valuable space. One of the newer and more exciting concepts is to use the hydrogen fuel of the proposed hypersonic aircraft as a heat sink to provide cooling for major areas of the airframe.

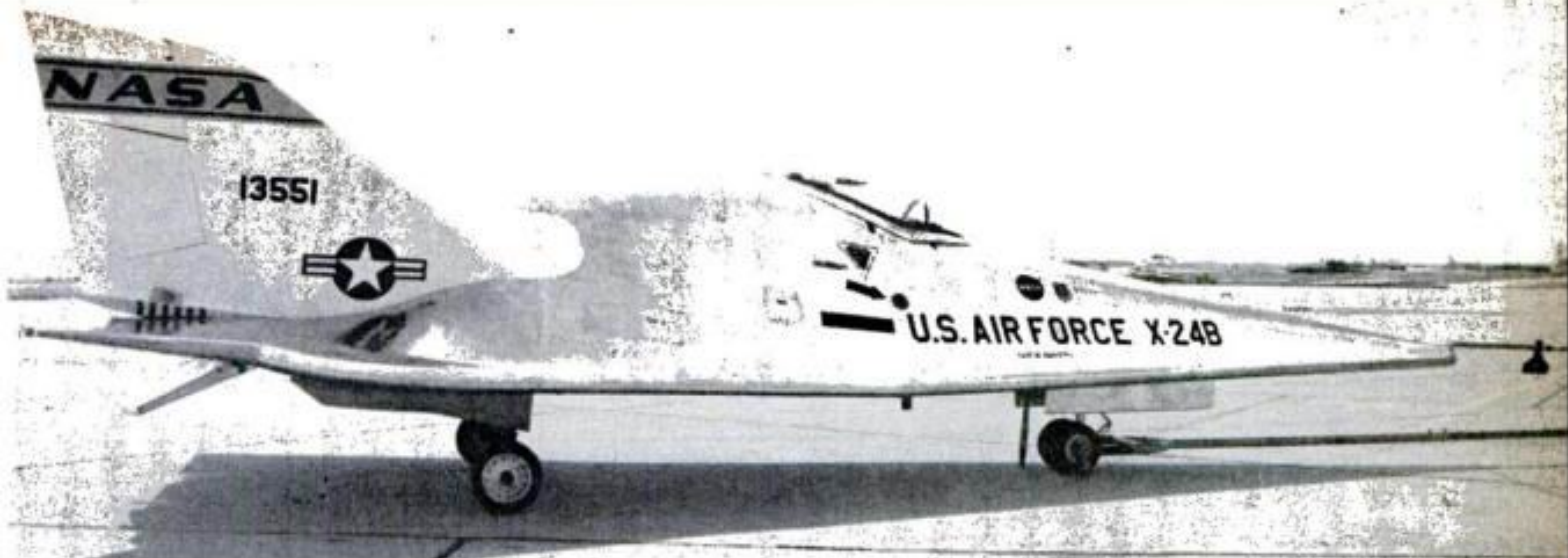
For NASA, solving the heat problem is secondary to the real payoff in basic flight research. This is a gain in our knowledge of the tricky things that air does to planes in the speeds between 700 and 1000 mph. It will let us go on from there to planes that routinely will fly at 3500 mph, and just as routinely land at commercial airports around the world.

It always shocks me to learn that science has a way of leap-frogging problems that remain unsolved. Somehow, having escaped to the

What powered flights of the X-24B lifting body will look like in profile



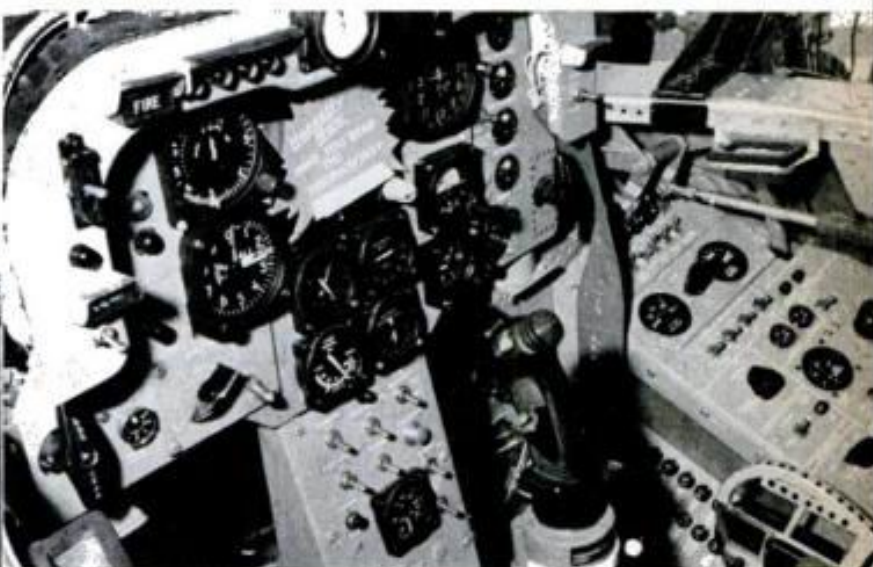
Schematic diagram shows flight profile for future powered flights. Normal drops are from 45,000 feet. Powered flights will last about 15 minutes. X-24B has advanced lifting-body design designated the FDL-8, shaped to lessen heating and provide lift and maneuverability without use of wings. This is essential for development of a space transportation system with aircraft that can operate in or near the Earth's orbit and still be able to land like an airplane. **Reaction Motors' XLR-11** rocket engine in the X-24B is the same four-chambered engine that powered the X-1 on its supersonic record flights in 1947. Five motors stored in museums were brought back in order to save money in the research program. Rocket thrust in these old engines is controlled by firing one or more chambers at a time. **Engines for future hypersonic planes** will possibly be combination ram and turbine jet, and burn hydrogen fuel rather than present JP-4. A converted B-52 is same one used to launch 140 X-15 rocket-plane flights and most lifting-body flights.



Side profile reveals "flatiron" look of the X-24B. Pointed nose added 14 feet to length of the former X-24A.



X-24B snuggles under B-52 mother ship hanging on same wing pylon used to carry the X-15 rocket ship and other lifting bodies for air launches over 40,000 feet.



Manke's fellow workers stuck note on cockpit panel before flight as a jest. The X-24B's control stick with trim buttons is visible at center right.

moon at over 24,000 mph, flown in rocket planes at 3500 mph, and gone supersonic in commercial airliners, you would think we knew all about going from subsonic to supersonic speeds. Not so. There are serious gaps in our knowledge. We know the blob heat-absorbing shape is ideal for a reentry body like the space shuttle, but there is still a lot to learn about the transonic speeds when aerodynamic changes are so great and mysterious that a plane could encounter strange flutters, tumble, and even be destroyed.

The ideal shape. The direct problem that planes like the X-24B hope to solve is to find an ideal shape for sustained transonic and hypersonic speeds so that they will be able to fly over 100,000 feet, where reaction jets would probably be used for control, as well as in the thicker air below, where aerodynamic controls could take effect.

The day before the first flight, I did some hangar flying with John Manke, the NASA research pilot. I watched him go through the last of

his 200 simulator flights preparing for the real thing.

Manke is one of three test pilots who have flown all three of the previous lifting bodies: the HL-10, M2-F3, and X-24A. The 24B is simply the 24A with a new long nose job and stubby wings.

Space shuttle. The X-24A was the Air Force's first attempt at a shuttle-vehicle design. A smaller unmanned version was launched into space. But the shape may change.

One Air Force research engineer told me the new pointed nose of the X-24B might be applied to the space shuttle because of its improved lift over drag characteristic. This could give it about twice the cross-range ability. It would be able to land within an area 1200-1500 miles wide after reentry from outer space instead of only 600-800 miles. The new shape is based on studies conducted at the Air Force Flight Dynamics Laboratory at Wright Patterson AFB.

Manke told me a bit about his flight and the controls. On the in-

strument panel there are two machometers, an angle-of-attack indicator, and a stopwatch. During landing the pilot is too busy looking out and judging elevation to steal a glance at the panel. Besides the stall-warning stick-shaker, which warns the pilot of too high an angle of attack, he is also constantly being talked down to the ground by two chase planes that fly close beside almost to touchdown.

The drop I saw was made almost directly over the landing area flying downwind. "Flying" is using the word loosely. The best glide ratio (distance forward to down) is about 5:1, but is usually about 2.8:1. This is about the same as the X-15 or an unpowered F-104. Compare this with the 20:1 glide ratio of a training glider or about 12:1 for a small private plane. The X-24B flies at about a 10-degree-up angle of attack. Incidentally, the angle of attack for reentry from space is 60 degrees.

Smooth drop. Manke described the drop as the "smoothest launch I

[Continued on page 141]

[NATURAL DISASTERS] CONTINUED

Another concept involves a squadron of cargo planes airdropping thousands of tons of a water-absorbing powder onto a hurricane to extract moisture from rain clouds. Dyn-O-Mat in Jupiter, Florida, manufactures superabsorbent products, such as garage mats designed to soak up oil from leaky cars. The firm is developing a gel that has shown promise in early trials. In July 2001, Dyn-O-Mat engineers dumped 8,000 pounds of their Dyn-O-Gel (an amount capable of absorbing 4,000 tons of water) over a small thunderstorm near the Florida coast. Within minutes, the storm disappeared from Doppler weather radar.

In a hurricane, the result would be two-fold. First, as the clouds dried out, the storm would wither. Then, as super-chilled Dyn-O-Gel droplets fell into the ocean beneath a storm, they would further weaken it by cooling the warm water that fuels its growth.

Dyn-O-Mat's founder and CEO, Peter Cordani, has already arranged to lease a specially rigged 747 "supertanker" to conduct trials on actual hurricanes. Meanwhile he has assembled an all-star team of scientists from labs at Florida State University, the National Center for Atmospheric Research, NOAA and elsewhere to begin running computer models that

Are hurricanes simply too big and powerful to respond to human-scale tinkering?

analyze the gel's effect on larger storms. "We already know the gel works," says Cordani, who lost his home during Hurricane Frances. "Now we need to figure out how much to use and where to put it."

Many scientists are skeptical, however. Chris Landsea, a hurricane expert with NOAA, wonders whether hurricanes are simply too big and powerful to respond to human-scale tinkering. "Thunderstorm activity alone could be equivalent to 200 times global electricity production," he points out. "It's just not physically feasible to make an impact." —MICHAEL BEHAR

[SPACE]

The Mini Shuttle

Russia partners with Europe to build its own reusable spacecraft for flights to the International Space Station and beyond.

WITH NASA'S BELEAGUERED shuttle still grounded over safety concerns—and given the unanswered questions about its replacement, the Crew Exploration Vehicle, which won't be ready to fly until 2012—the European Space Agency is mulling an option to buy its own ride to space. This month ESA plans to request \$60 million from its member states to help Russia prepare its new, reusable spaceship, the Clipper, for a crewless test flight by 2011 and a manned flight by 2012.

The six-person Clipper is designed to replace Russia's three-person Soyuz capsule, which has been in operation since the 1960s and is currently the only reliable transport to the International Space Station. Lighter than NASA's shuttle and more powerful than the Soyuz, the Clipper will be more than just a taxi to the ISS. Notes ESA official Manuel Valls, "It could go to the moon."

The Russian Federal Space Agency showed off a full-scale mock-up of the craft at the Moscow International Air Show in August. If all goes well—that is, if ESA ponies up funding—design studies of the Clipper could begin in early 2006. —DANIEL CLERY

GETTING INTO SPACE

The 13-ton Clipper is nearly twice the weight of the Soyuz capsule and thus requires a stronger launcher. Russian engineers are considering several options, including the Ukrainian-built Zenit and a yet-to-be-developed Russian rocket called the Onega [pictured here], which is essentially a beefed-up version of the Soyuz launcher.



CREW CABIN

The 21-foot-long passenger cabin and reentry vehicle will accommodate six crew members (two pilots and four other astronauts or tourists), plus 1,100 pounds of cargo—more than 10 times that of the Soyuz.

LIVING ROOM

The 13-foot-long detachable habitation module contains life-support systems, including a toilet, as well as the docking port for the International Space Station.

POWER THRUSTERS

The instrument module houses thrusters to separate the Clipper from its launcher and to maneuver the spacecraft. It also contains the electrical system, which is powered by extendable solar arrays. Both the instrument module and the habitation module are jettisoned before reentry.

HEAT SHIELD

The craft's exterior consists of heat-resistant ceramic panels designed to endure several flights before requiring replacement.

TWO LANDING OPTIONS

The craft's stubby wings enable the pilot to steer during the descent and make a controlled landing on an airport runway. In case of an emergency, parachutes ensure that the Clipper can land safely on the plains of central Russia.





5 MODEST PROPOSALS TO SAVE THE PLANET

The obvious first step in any environmental strategy is to stop mucking up the environment. If that doesn't work, we'll need to get creative

BY RENA MARIE PACELLA ILLUSTRATIONS BY GRAHAM MURDOCH

RE-ICE THE ARCTIC

Salty ice could keep ocean currents flowing

WHERE: NEAR GREENLAND

COST: \$50 BILLION

THE PROBLEM: Arctic ice is melting, diluting the salty seas with freshwater and, many suspect, weakening the ocean currents that help regulate the global climate by transporting heat around the globe. If these currents were to shut down, the consequences would be unpredictable and dire: immense loss of marine life and fisheries; a reduction in the ability of the ocean to remove greenhouse gases

from the atmosphere; and, some scientists speculate, drastic cooling of Northern Europe.

THE FIX: Make more Arctic ice, and make it salty. Under normal conditions, warm-water currents like the Gulf Stream carry heat from the tropics to Europe. After a current releases its heat, the water sinks (cold water is more dense than warm; salty more

dense than fresh) and flows back to the equatorial regions along the ocean floor. This sinking is the engine that powers global currents. But in one apocalyptic scenario, melted Arctic ice dilutes the water in the North Atlantic to the point where the tropics-bound current isn't dense enough to sink. The heat-carrying currents skid to a halt, and Europe enters a new ice age.

Industrial engineer Peter Flynn of



PROPOSITION: Will we use technology to suppress a hurricane by 2009?

PPX BET ON THE FUTURE
AT PPX.POPSCI.COM

the University of Alberta proposes a bold way to boost currents if they begin to slacken: Tow 8,000 ice-making barges to the Arctic, and make a salty ice cube the size of New Mexico. In this plan, the barges would arrive off the coast of Greenland in the fall. As winter set in and air temperatures fell below 14°F, wind-powered water pumps on the barges would shower salty seawater on top of the existing

ice pack, creating new layers of extremely salty ice.

Come spring, the barges would boost the currents by spraying more water onto the newly formed saline ice pack. As it melted, the cold, dense, salty water would sink into the deep ocean. The result: a 6 percent increase in down-welling currents, enough to keep the system moving along.

NEXT STEPS: Flynn does not advocate implementing this solution now—only if the slowdown reaches a critical threshold (what that threshold is and when it may occur is still in question) and only if all else fails. It's not a plan B, he says; it's a plan D. Instead, a better course of action would be to ensure that the down-welling currents and ocean conveyor belt not be suppressed in the first place.



TAME STORMS WITH COLD WATER

A million straws could mellow the next Katrina

WHERE: GULF OF MEXICO **COST:** \$5 BILLION

THE PROBLEM: Climate change is warming the oceans. Warm oceans fuel hurricanes, which draw their energy from the heated, moist air at the sea surface. As sea temperatures continue to rise, some scientists warn that tropical storms will intensify.

THE FIX: Cool down the warm surface water that storms need to grow. New Mexico inventor Phil Kithil wants to put 1.6 million ocean-cooling "pumps" into the Gulf of Mexico, anchor them to the seafloor, and watch as they turn category-4 whoppers into category 3s, and 3s into 2s. It would take four months, some 100 barges and \$5 billion to install, but once in place, the 1,000-mile-long band of water coolers would kick in whenever a storm started brewing.

Next month, Kithil will set sail for Bermuda with 10 of his wave-powered pumps and attempt to cool a one-third-square-mile patch of sea. Dropped from the deck of his ship, spools of barrel-width flexible tubing will unravel to form 650-foot-long cylinders. These are topped by buoys that bob up and down with each passing wave and drive pumps that draw cool, nutrient-rich water up from the deep ocean. Bigger waves mean more cooling, and, conveniently, big waves precede hurricanes. "So we get cooling only when we want cooling," Kithil says, "when there's a hurricane on the horizon."

His company, Atmocean, has already tested individual pumps, and they temporarily lowered surface temperature by 7°F. The results might not be so dramatic in the large-scale trial, but models show that even a 1°F drop would reduce hurricane winds by 5 percent. According to Kithil, a drop in wind speed from 120 to 110 mph would reduce property damage by 23 percent.

NEXT STEPS: Kithil's team will measure the effects on marine life. They hypothesize that the water's increased nutrient levels will improve the health of the ocean food chain and possibly enhance the ocean's natural ability to sequester carbon by encouraging the growth of plankton (also a food source for fish) near the sea surface.

GROW SUPER-TREES IN FACTORIES

How robot-run factories will save the rainforest

WHERE: RAINFORESTS **COST:** \$120,000 PER SQUARE MILE

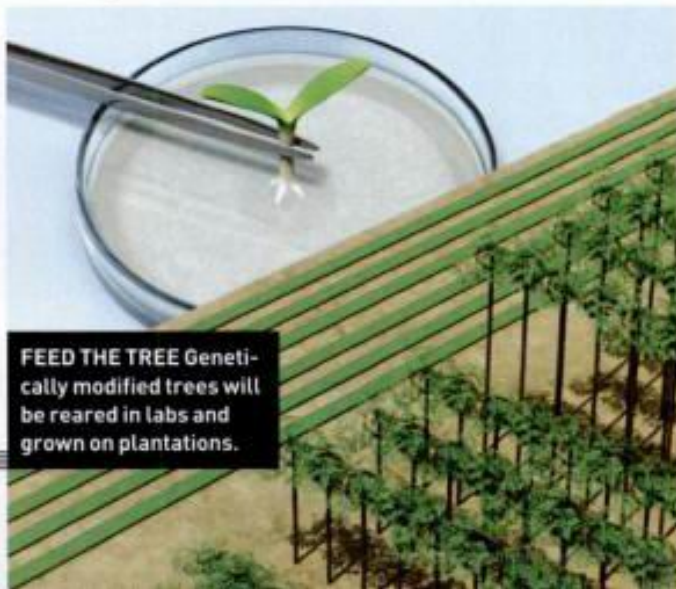
THE PROBLEM: The world's rainforests lose 100,000 acres and as many as 100 species every day. The Amazon alone loses 10,000 square miles a year. As the demand for timber (used for wood, paper and biofuel, among other products) increases, experts predict that the rainforests could be wiped out by 2050—and with them, the habitat for half of the world's species of plants, animals and microorganisms and the source of 25 percent of all pharmaceuticals.

THE FIX: Genetically modified tree plantations that will undercut the market for cheap rainforest wood. ArborGen, a biotech company in Charleston, South Carolina, is spearheading research that will help farmers mass-produce trees on 5 percent of the land currently required. It will also eliminate the need to ever again fell a native rainforest tree for timber (clear-cutting for farmland will not be affected).

Since 2000, the company has been identifying useful genes from half a dozen tree and plant species to produce trees with desirable traits like fast growth, stress tolerance and reduced lignin (the material that must be chemically removed to make paper). For example, by speeding up the trees' growth cycle, ArborGen is on track to decreasing the time it takes to harvest pine trees from roughly 30 years to about 18. It's also created a low-lignin eucalyptus tree that's perfect for pulping.

The two big hurdles are time and money. Transgenic trees are painstaking and expensive to cultivate. Even after scientists develop a new line of trees, they must still handle each seedling individually, from petri dish to plantation.

NEXT STEPS: To make this approach economically viable, ArborGen plans to churn out the designer seedlings in fully automated tree factories, so it has begun designing the robots that will transplant and evaluate seedlings autonomously. The company hopes it can also save endangered tree species—one project aims to splice blight-resistance genes into the near-extinct American chestnut tree.



FEED THE TREE Genetically modified trees will be reared in labs and grown on plantations.



BUILD WETLANDS FROM SCRATCH

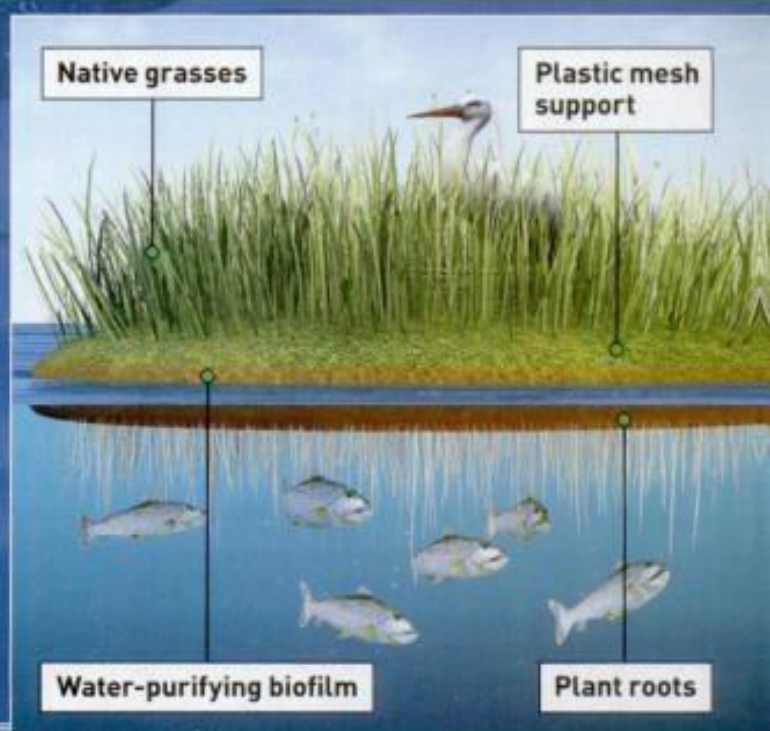
Save coastal marshes and clean up polluted waterways with plant-covered rafts

THE PROBLEM: The wetlands are losing ground. Crops and condos are rapidly overtaking much of the water-logged land—home to thousands of bird and animal species—while pollution and sea-level rises take care of the rest. With this loss comes drastically reduced water quality, increased flooding of surrounding areas and the looming specter of the extinction of many species.

THE FIX: Construct archipelagos of boat-size to basketball-court-size islands out of recycled plastic and foam, plant habitat-specific vegetation, and set the islands afloat wherever natural wetlands once thrived.

Along with rainforests and coral reefs, wetlands are the most active and diverse ecosystems on the planet, serving as a home or breeding ground to one third of all bird species, 190 amphibians and more than 200 types of fish. Wetlands filter out excess nutrients and pollutants by trapping them in roots and soil where plants and bacteria break them down into less harmful substances.

To mimic wetlands, inventor Bruce Kania starts with layers of polymer mesh bonded together with adhesive foam and carpets them with sod and wetland vegetation. Plants are



INSULATE THE GLACIERS

Huge blankets in the Alps could prevent a big thaw

WHERE: SWISS ALPS COST: \$12 MILLION PER SQUARE MILE

THE PROBLEM: Glaciers—Earth's largest freshwater reservoir, collectively covering an area the size of South America—are melting away, shrinking by up to hundreds of feet per year in some places. The Alps alone stand to lose three quarters of its glaciers by 2050, and what's left by the end of the century.

THE FIX: Wrap thawing glaciers in football-field-size synthetic blankets that keep the cold in and the heat out. At least that's what ski resorts in the Swiss Alps are doing. Tired of risking the fate of their industry on the global community's ability to get a grip on rapid climate change, more than a dozen resorts turned to local textile company Fritz Landolt to stop the melting. Called the Ice Protector, Landolt's material is a tough but lightweight dual-layer composite. On top is polyester to reflect ultraviolet light, and on the bottom is polypropylene, a polymer used in military clothing and auto parts, to block heat. When wrapped around a glacier, it prevents the top snow layer—and, it's hoped, the permanent ice underneath—from melting in the summer sun.

After a small pilot project in 2005 on the shrinking Gurschen glacier proved hugely successful—the blanketed area had 80 percent less melt than surrounding ice and snow two years in a row—Landolt has been tackling bigger and bigger ice packs, including an area the size of six football fields (more than 300,000 square feet) on the Vorab glacier, home to one of Switzerland's largest ski resorts.

NEXT STEPS: Don't count on the blankets saving the snows of Kilimanjaro. With the ski resorts footing the bill, their use is limited to critical areas where melt directly interferes with skiing and snowboarding. But there's always the burgeoning beer market. "We had a guy throwing an outdoor party last summer," says Landolt product manager Marcel Stahle. "We sold him 100 square feet. His beer stayed cold all day."

BOBBIN' FOR BIRDS The same adhesive foam that makes boats buoyant keeps these artificial ecosystems afloat.

WHERE: COASTAL AREAS

COST: \$800 MILLION PER SQUARE MILE OF ISLAND

selected to attract insects, frogs, waterfowl, beavers or whatever wildlife is native to the area. As the plants grow, their roots weave their way through the plastic matrix to the water below. Microbes cling to the polymer fibers and colonize the root system, forming a slimy layer of "biofilm" that purifies the water and oxygenates it. (It is unclear whether the islands will help limit flooding.)

Kania first tested his "BioHavens" in algae-infested ponds on his farm in Montana. The BioHavens filtered fertilizer runoff and suppressed harmful algal blooms in the ponds. Now some 3,000 of these ready-made ecosystems are floating at trouble spots around the globe, including a chain of BioHavens in a reservoir in Singapore that absorb waterborne pollutants.

NEXT STEPS: Kania is confident that his islands work, but he may soon receive independent data that will prove it. Consulting engineer Frank Stewart, with a two-year grant from the state of Montana, is wrapping up water-quality tests conducted on the BioHavens in huge fish tanks. They could provide the first solid evidence that the islands clean water.



EASY DOES IT Six people can roll out 15 of these 330-foot glacier blankets in two weeks.

The Great Big Telescope

By Dawn Slovic

A huge telescope under construction in a remote West Virginia valley will listen for whispers from the heavens.

OPERATORS OF the largest telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia, knew something was wrong when pieces of the control room ceiling began falling on November 15, 1988. Soon afterward, the 26-year-old telescope, with a dish antenna 300 feet in diameter, collapsed under its own weight. Years worth of research had to be put on hold while astronomers scrambled to apply for observing time on smaller telescopes.

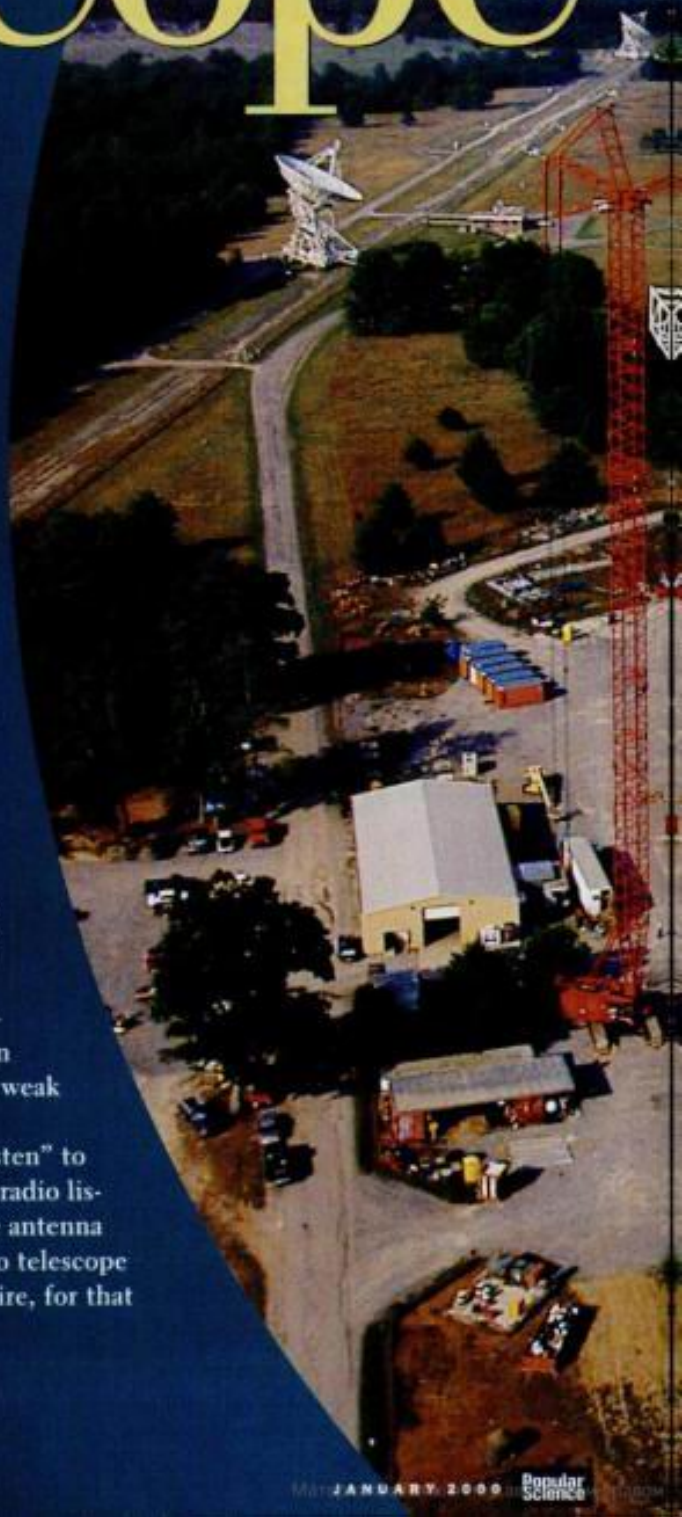
The only good news for astronomers was that Congress quickly granted the observatory \$75 million to begin building a replacement, thanks largely to the influence of Senator Robert Byrd of West Virginia, the ranking member on the Senate Appropriations Committee. Finally nearing completion, the new Green Bank Telescope is

not only bigger than its predecessor—it will be the largest fully steerable radio telescope in the world—but also uses a radical new design that will make it easier to detect weak radio signals from space.

A radio telescope doesn't really "listen" to radio signals, any more than your car's radio listens to FM stations. In both cases, the antenna simply collects radio waves. But a radio telescope uses a large dish, instead of a rod or wire, for that



A giant radio telescope (right) is nearing completion in Green Bank, a town within the National Radio Quiet Zone—which includes large portions of West Virginia and Virginia (above)—that's surrounded by National Forest (dark green).



PHOTOGRAPHY JOHN B. CARNETT
INFOGRAPHICS JOHN MACNEILL



purpose. And instead of translating radio waves into sounds, the telescope turns them into graphs or images that astronomers can use to observe distant objects in the universe.

The radio signals collected by the Green Bank Telescope can tell astronomers about the molecular components of these distant objects.

Astronomers can then study molecules in the regions where new stars are forming, for example, to learn more about this process. The telescope will also help astronomers find pulsars, spinning neutron stars that throw out radio beams like a lighthouse. The radio signals from pulsars can be used to probe the properties of interstellar space. The telescope could even be used to listen for messages from extraterrestrial civilizations.

The radio signals coming from objects in distant galaxies are very faint, so astronomers need huge antennas to capture these signals. If you took all the radio energy falling on all the radio telescopes around the world and put it together, it wouldn't be enough to power a light bulb. But the bigger the telescope, the more weak radio signals it can collect—just as a larger bucket collects more raindrops. With a dish 100 meters across, the new Green Bank Telescope will be among the largest in the world. Astronomers joke that its abbreviation, GBT, actually stands for Great Big Telescope.

But size isn't everything: The GBT's shape is what makes it more efficient than another telescope of the same size located in Effelsberg, Germany. "What's so different about [the GBT] is its offset feed arm," explains Mark McKinnon, a scientist at the Green Bank observatory site.

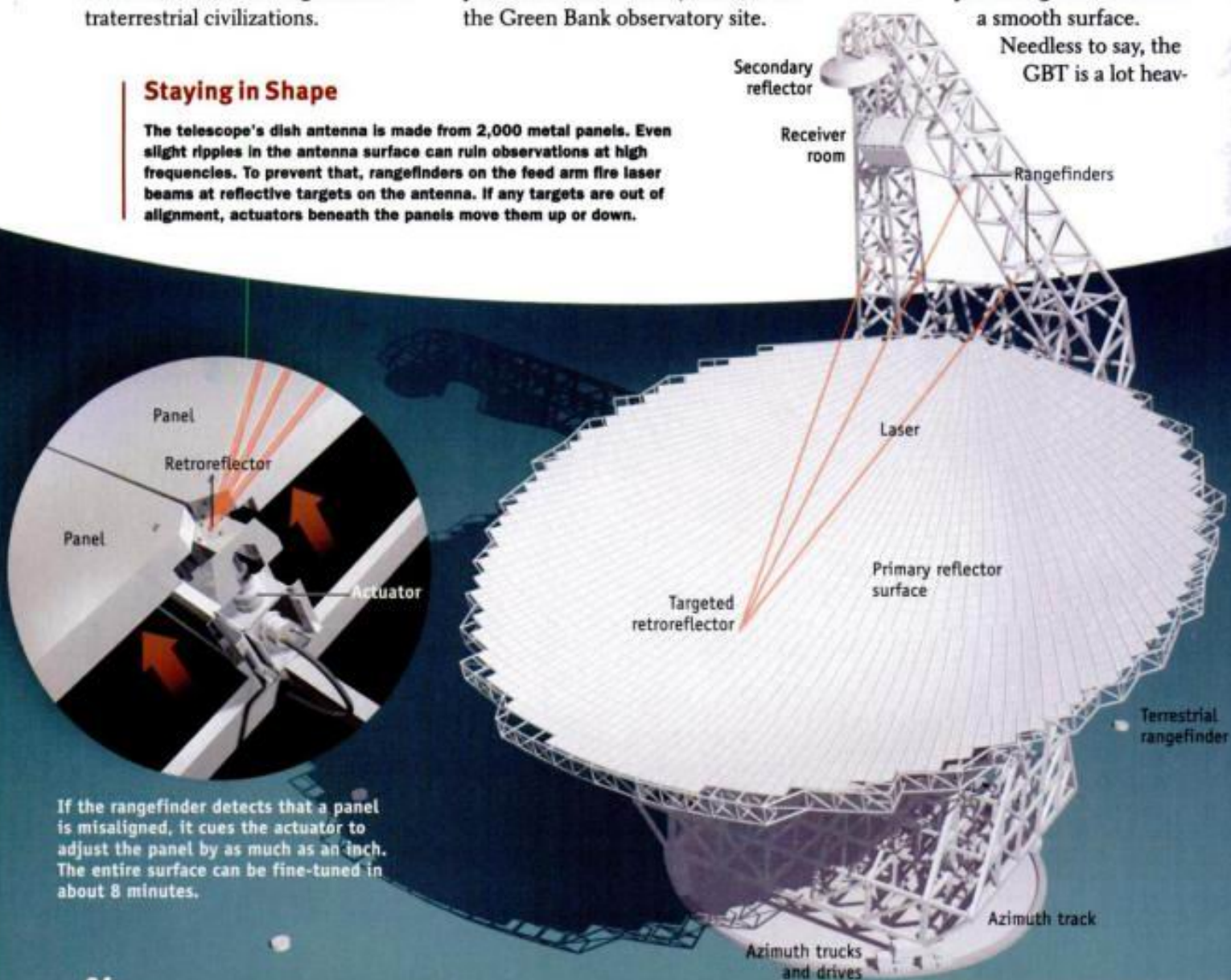
In a conventional radio telescope, a parabolic dish focuses radio signals on a receiver suspended above the center of the dish on support arms. The receiver, like the eyepiece of an optical telescope, collects the focused radio waves. But the support arms block some of the incoming radio signals from reaching the dish. With the offset design, that won't happen. Also, the telescope won't be as susceptible to the interference generated by nearby ground-based radio sources.

The GBT is like a jumbo version of a pizza-size satellite TV dish. The surface of the antenna is 100 meters wide and 110 meters long, and the receiver arm is off to one side of the dish. But while a TV dish antenna is made from a single piece of metal, the GBT's dish consists of some 2,000 aluminum panels that are pieced together to create a smooth surface.

Needless to say, the GBT is a lot heav-

Staying in Shape

The telescope's dish antenna is made from 2,000 metal panels. Even slight ripples in the antenna surface can ruin observations at high frequencies. To prevent that, rangefinders on the feed arm fire laser beams at reflective targets on the antenna. If any targets are out of alignment, actuators beneath the panels move them up or down.



If the rangefinder detects that a panel is misaligned, it cues the actuator to adjust the panel by as much as an inch. The entire surface can be fine-tuned in about 8 minutes.

NEWSFRONTS

SCIENCE & TECHNOLOGY

EDITED BY DAWN STOVER

AVIATION

Space Hopper

DAIMLERCHRYSLER Aerospace is studying a new design for a reusable space launch vehicle, and could fly a small test craft by 2002. The full-size craft, named Hopper, would be about as large as the space shuttle orbiter and could put a 6-ton satellite into geostationary orbit. It could be operational by 2015.

Hopper gets its name from the fact that the vehicle does not fly all the way into orbit. Instead, the craft jumps to a suborbital altitude of more than 90 miles, where it coasts above the atmosphere as its satellite payload slides out of the rear-opening cargo bay. A small "kick-stage" rocket then boosts the satellite into orbit.

Hopper takes off from a sled, running on a 1.5-mile-long track at the European space launch center in Kourou, French Guiana. The sled permits a faster liftoff speed than wheels do, which means the Hopper's delta wing can be smaller and lighter, and its landing gear does not have to bear the 340-ton weight of the fully fueled vehicle.

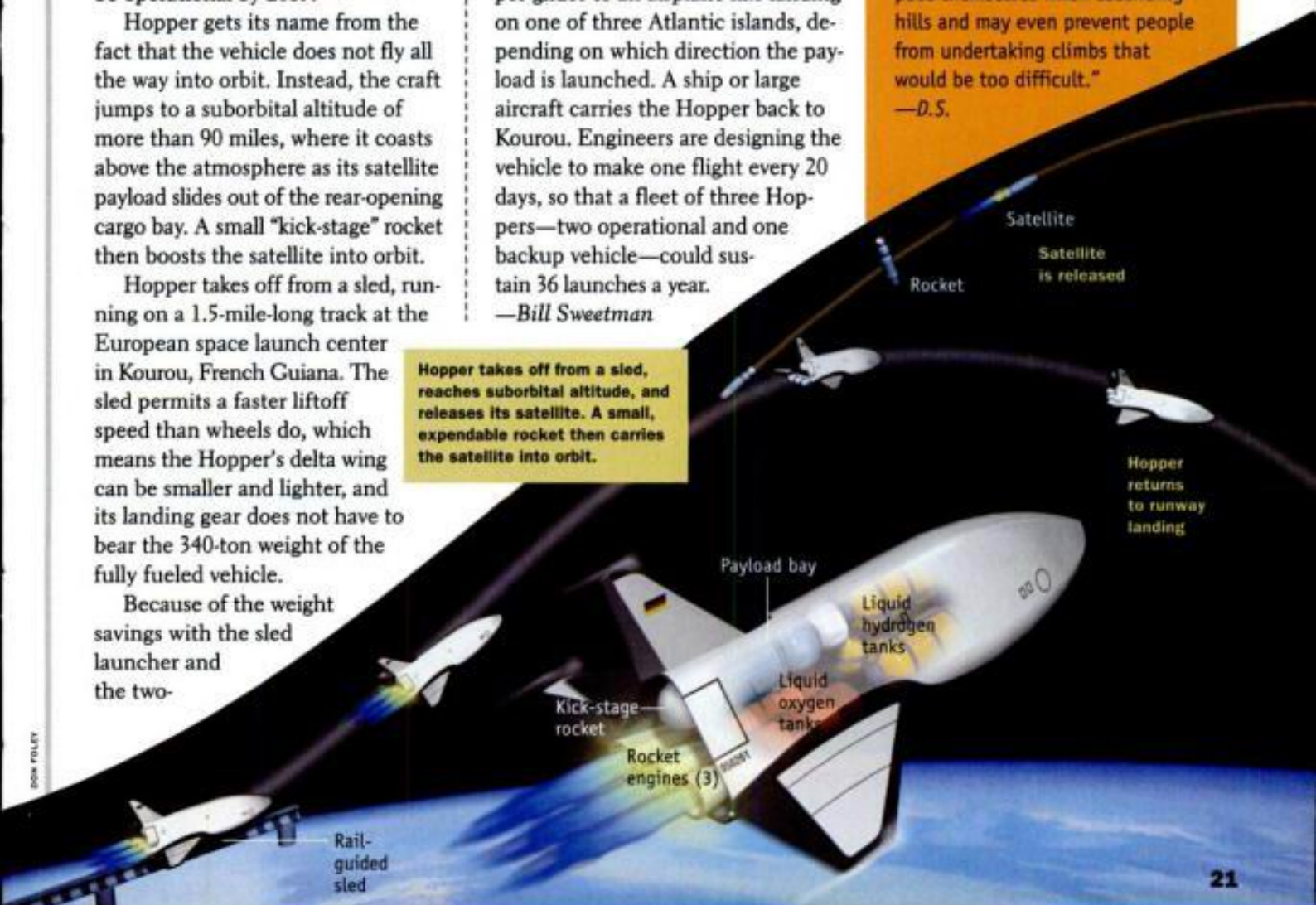
Because of the weight savings with the sled launcher and the two-

stage design, Hopper does not rely on exotic materials or new engines—unlike the single-stage-to-orbit VentureStar proposed by Lockheed Martin and NASA. Hopper does not need composite fuel tanks, which are proving to be a major headache for the builders of the VentureStar's predecessor, the X-33, and it uses the same engines as Europe's Ariane 5 expendable rocket.

After releasing its payload, Hopper glides to an airplane-like landing on one of three Atlantic islands, depending on which direction the payload is launched. A ship or large aircraft carries the Hopper back to Kourou. Engineers are designing the vehicle to make one flight every 20 days, so that a fleet of three Hoppers—two operational and one backup vehicle—could sustain 36 launches a year.

—Bill Sweetman

Hopper takes off from a sled, reaches suborbital altitude, and releases its satellite. A small, expendable rocket then carries the satellite into orbit.



PSYCHOLOGY

Uphill Battle

TO MOST PEOPLE, hills look a lot steeper than they really are. Just ask University of Virginia psychology professor Dennis Proffitt.

He recruited students to guess at the slant of two hills, one with a 10-degree incline and the other a 5-degree. The students estimated the hills to be about 30 degrees and 20 degrees, respectively, and were shocked to learn the truth.

Exaggerations are beneficial, Proffitt says. "They help people pace themselves when ascending hills and may even prevent people from undertaking climbs that would be too difficult."

—D.S.

SPACE

GO TO MARS, HAVE A BALL!

Round robotic sidekicks scout Martian territory for the next generation of rovers

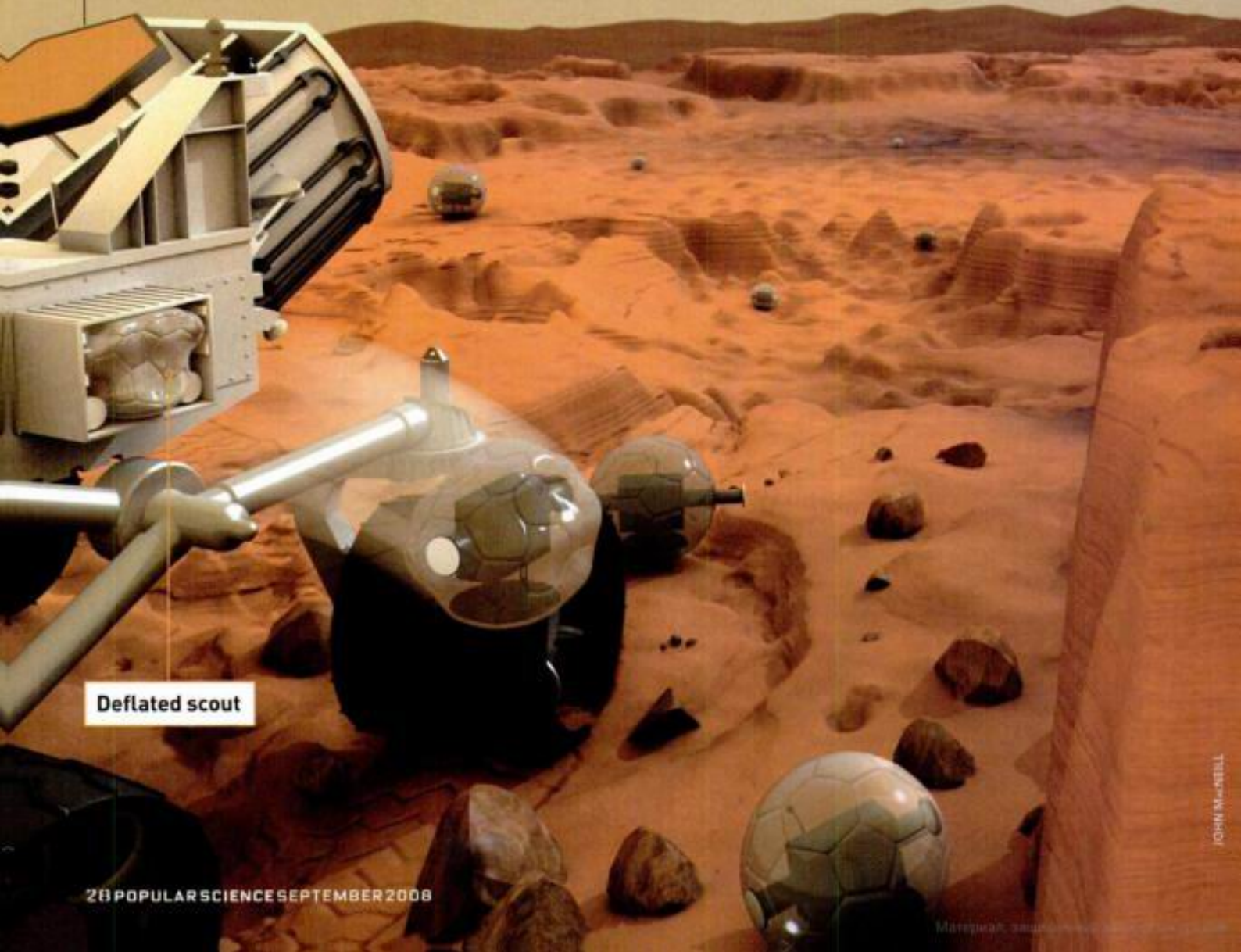
BY NEXT FALL, NASA plans to launch its biggest Red Planet rover yet, the \$1.8-billion, SUV-size *Mars Research Laboratory*. Even though the *MRL* will be able to haul five times as much equipment as the *Spirit* and *Opportunity* rovers that are already on Mars, a group of Swedish researchers say that they could accomplish far more if accompanied by a squad of helper 'bots. Fredrik Bruhn, the CEO of Ångström Aerospace Corporation, and his colleagues have designed the small inflatable scouts to

assist bigger, less mobile rovers in their hunt for signs of microbial life on Mars.

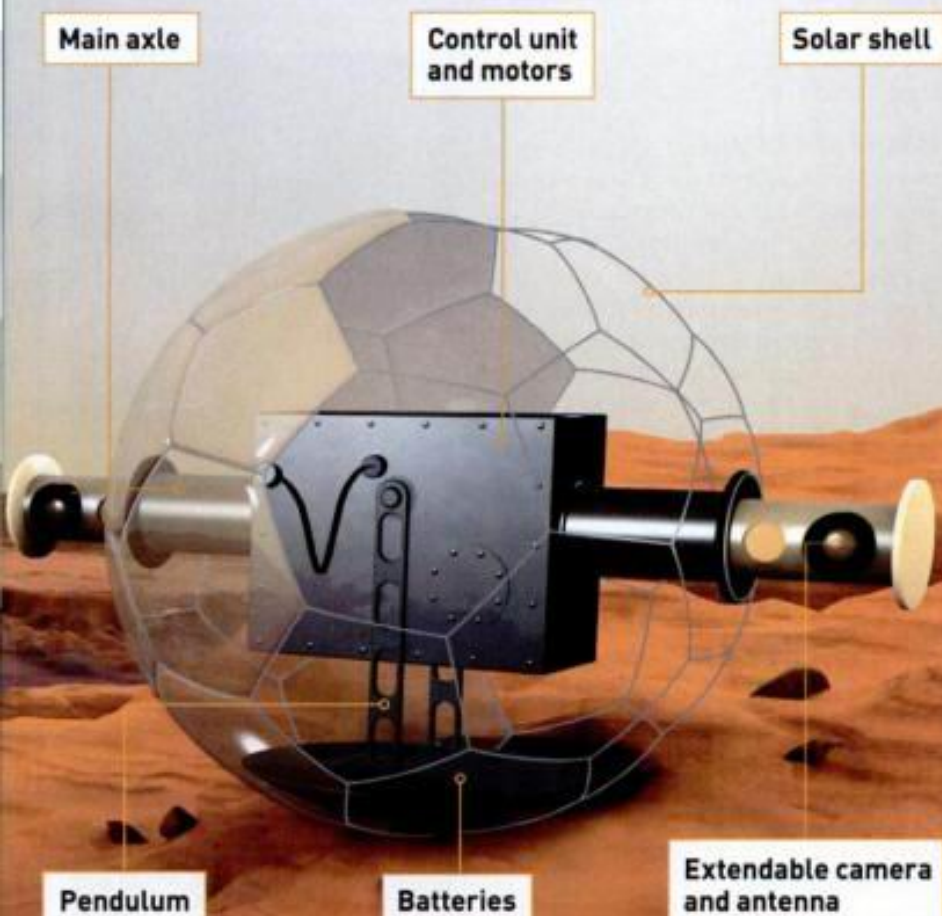
Each foot-wide, 11-pound ball can roll up to 62 miles, snap photos at any angle, and take soil samples, drawing its power from the solar panels on its shell. Unlike wheeled rovers, the rounded scouts have fewer motors to repair, never flip over, and are easier to seal from dust. Plus, they rarely get stuck. "The beauty of the system is it needs very little energy to go around rocks, so unless you're landing on a surface that looks like a bed

of nails, it should be fine," Bruhn says.

In 2004, Bruhn helped found Swedish company Rotundus, whose Earth-based GroundBot is now test-patrolling a harbor in Stockholm. By using GroundBot's pendulum-propulsion mechanism, swapping in a radiation-proof computer, and designing a lightweight, inflatable shell, he thinks he could produce four of the Mars balls for as little as \$6 million. "We just need to assemble the bits and pieces and test it," says Bruhn, who shows his design to NASA officials this month. —COREY BINNS



Deflated scout



ROLLING OVER THE RED PLANET

INFLATION: The deflated scouts are stored in boxes aboard the *Mars Research Laboratory*. After landing, a latch opens the box, and a spring inside gently rolls them onto the Martian surface. This motion triggers a canister of xenon gas inside the ball to release and inflate the scouts before they hit the ground.

EXPLORATION: Each ball runs on two solar-powered motors. One motor swings a pendulum to move the ball's center of mass, building forward- or backward-moving momentum. To turn, a second motor

tilts the pendulum along the main axle—"the same physics used to fly a helicopter," Bruhn says. The robot can automatically decrease its internal pressure to more easily roll over soft surfaces and patches of sand.

COMMUNICATION: The autonomous scouts would collect data on the conductivity and age of the Martian terrain, take photos, and send information back to the *MRL* and ground control. The *MRL* serves as the scouts' communication hub, receiving and transmitting messages from each ball.

(CONTINUED FROM PAGE 27)

tion including the time and amplitude of the shaking—to a central computer. "It's looking for large numbers of triggers coming in all at once," Lawrence says. That's the signature of an earthquake, and a cue for the computers to relay detailed data about the event.

Users can register their five favorite locations so that their laptops will know where they are when the shaking is detected. Even if the user isn't at one of those locations, Lawrence says that in urban areas, "we can figure out where you are within about a mile"

The more laptops that join, the faster the network can detect earthquakes.

based on the IP address used to transmit the data. The network has already detected a magnitude-5.1 quake just west of Reno, Nevada. It's especially suited to areas too vast or budget-strapped to deploy more sophisticated sensors, which often cover too little ground to get an accurate reading and tend to go off scale during heavy shaking.

While QCN can only detect a quake after it starts, that may still provide enough time to prepare for the stronger shaking that follows. Digital data travels faster than seismic waves, so even though it might take several seconds for the QCN headquarters to register the first wave, that would still allow enough time to slow down a train or close a gas valve before the secondary wave strikes. In fact, experts estimate that just a five-second warning can reduce the death toll of a major quake, such as the one that killed at least 69,000 people in China last May, by as much as 80 percent.

But first QCN creators must work out the thorny details of how to issue warnings without stepping on any official toes or causing mass panic. And they have to recruit foot soldiers. So far, only a few hundred people have volunteered for QCN. But the more computers that are part of the network, the faster it works. "To do early warning, we'd want at least 1,000 [volunteers] for the Bay Area," Lawrence says. As it grows, the network might include iPhones and Wii remotes, which are also equipped with accelerometers. Ready to enlist? Visit qcn.ucr.edu.

—DAWN STOVER

The bleak era of PCs in rectangular boxes may finally be over.

By Chris O'Malley

Radical Chic



Movable Feast

The tilting TFT (thin film transistor) screen folds flat when you want to move the computer, and there's space above the mouse holder where you can stow the keyboard.

FINALLY, A HOME COMPUTER you won't want to hide away in the spare bedroom. That's one reaction to Compaq's striking new Presario 3000 system, with its flat-panel color

display suspended against a speaker-grille backdrop. Another reaction: Is this really a personal computer?

Yes, it's a PC, and a deceptively high-powered one at that. The first model in a new line, the Presario 3020 has a 166MHz Pentium processor inside, accompanied by 16 megabytes of memory, a 2-gigabyte hard disk, a 33.6 modem, a four-disc CD-ROM changer, and JBL stereo speakers with Spatializer surround-sound. There are even *four* expansion slots tucked horizontally in the rear.

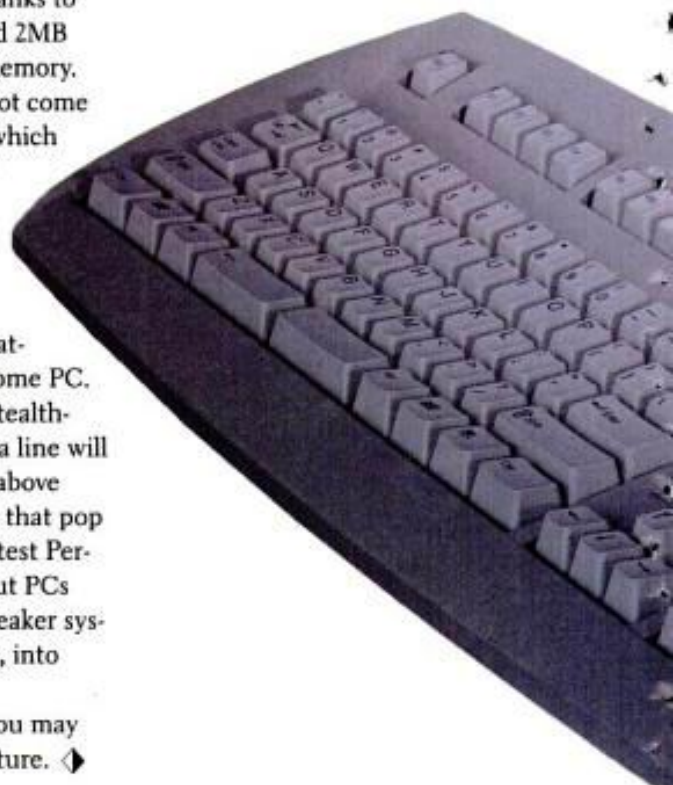
But the sleek design is what really moves you—and moves with you. The Presario's slender shape, coupled with a built-in handle and holders for both the keyboard and cordless RF mouse, lets you quickly transport the PC from the family room to the kitchen. (You'll need an AC outlet, though; there's no battery operation.) And the 12-inch LCD screen is lustrous enough to work or play in any

room, because of unusually bright dual-lamp backlighting. Video clips look remarkably smooth, thanks to MPEG software support and 2MB of high-speed videoboard memory.

Computer cachet does not come cheap. The Presario 3020, which comes preloaded with Windows 95 and a host of other software programs, is expected to sell for about \$3,500, a hefty premium.

Compaq is not alone in attempting to redesign the home PC. Due in September, a new stealth-black model in IBM's Aptiva line will feature a monitor perched above floppy and CD-ROM drives that pop up from its base. Apple's latest Performa 6400 and Sony's debut PCs each integrate complete speaker systems, including subwoofers, into their hardware.

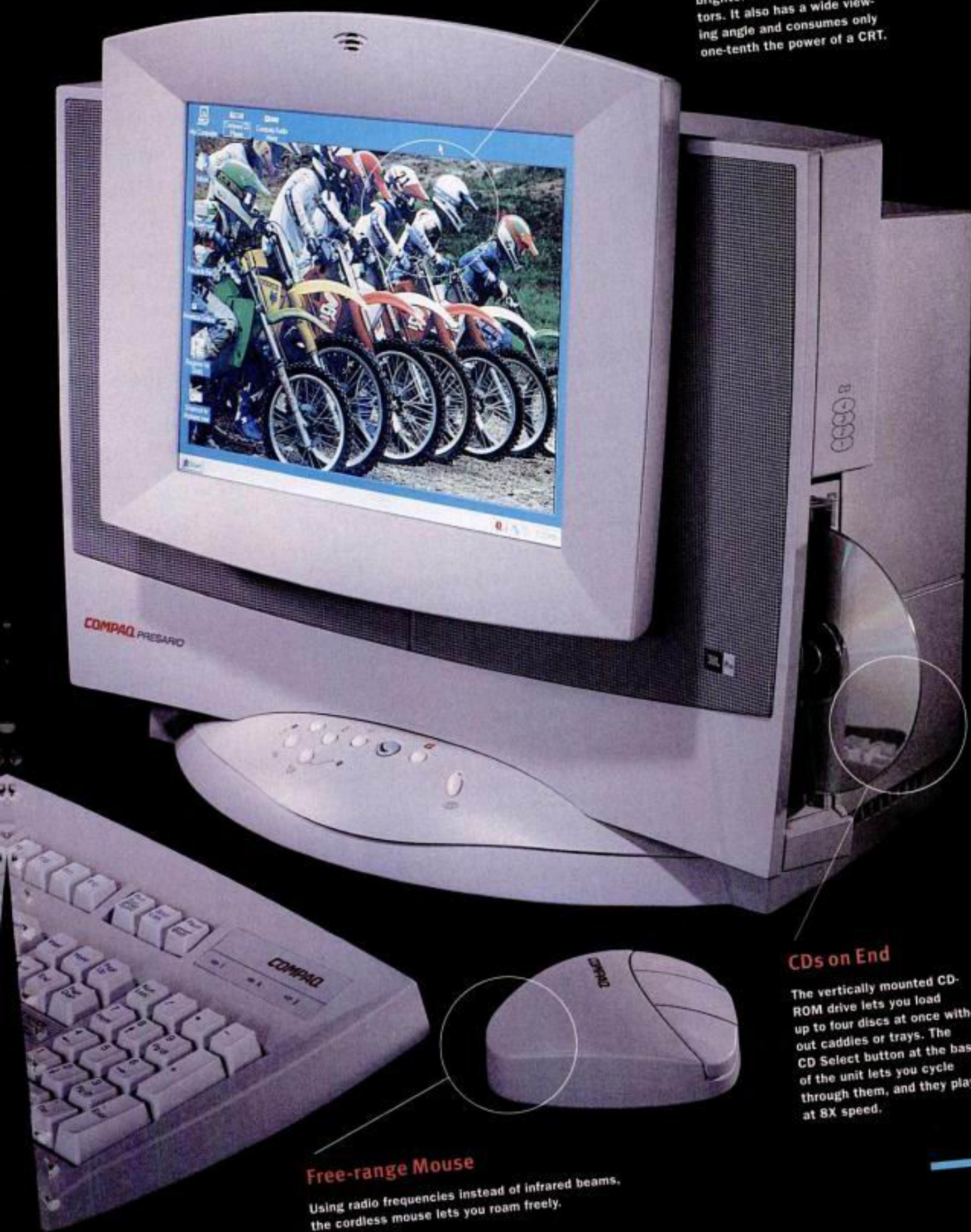
Heck, with these PCs, you may need to upgrade your furniture. ♦



PHOTOGRAPHED BY JOHN B. CARNETT

Looking Sharp

The 12.1-inch (diagonal) color LCD screen is twice as bright as a typical laptop screen, and up to 60 percent brighter than desktop monitors. It also has a wide viewing angle and consumes only one-tenth the power of a CRT.



CDs on End

The vertically mounted CD-ROM drive lets you load up to four discs at once without caddies or trays. The CD Select button at the base of the unit lets you cycle through them, and they play at 8X speed.

Free-range Mouse

Using radio frequencies instead of infrared beams, the cordless mouse lets you roam freely.

How Digital Cameras Work

PC-TV Arrives

The Best New Sedans

Why Airplanes Crash

Popular Science

Inside the INDY CAR

THE TECHNOLOGY OF RACING

THE TACTICS

THE TEAMS

THE CARS



A TIMES MIRROR MAGAZINE
APRIL 1996 \$2.95
CANADA \$3.50

Illustration: Michael Leung/Williams F1

Silicon Under the Fingernails

By A.B. Shuman

The computer power of a space shuttle

is packed under the carbon skin of an Indy car. But it's still possible to run out of fuel.

AN INDY CAR DRIVER IS ALONE in the cockpit, but technology wires the pilot inexorably to his pit crew. An onboard computer monitors and controls much of the engine and chassis performance—almost recreating the early, pre-1937 days of racing, when Indy cars had a riding mech-

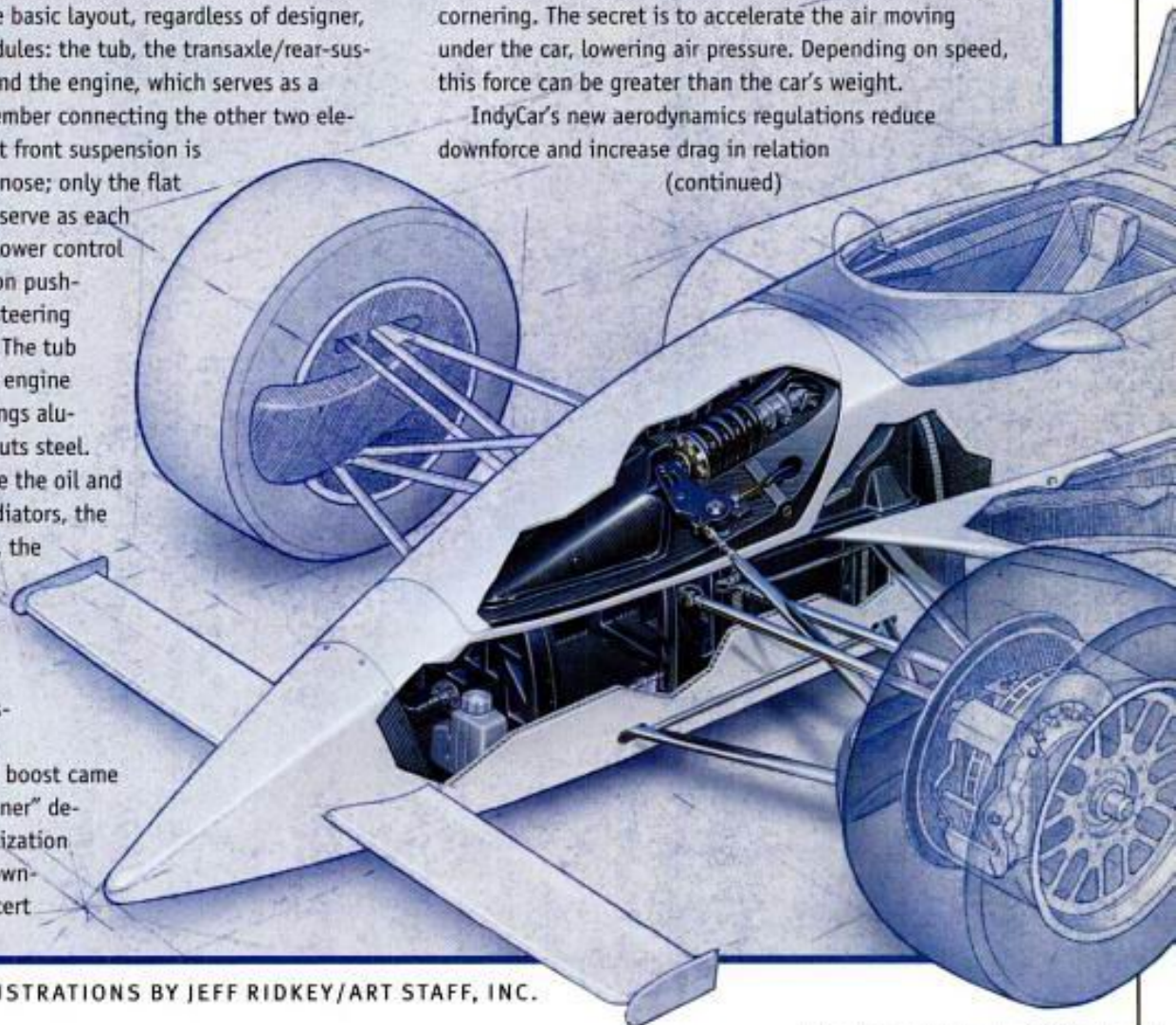
The Body: Speed Is in the Design Details

THE MOST IMPORTANT DESIGN consideration for an Indy car? Packaging. The basic layout, regardless of designer, has three main modules: the tub, the transaxle/rear-suspension package, and the engine, which serves as a stressed chassis member connecting the other two elements. The compact front suspension is hidden in the car's nose; only the flat tubular struts that serve as each wheel's upper and lower control arms, the suspension push-pull rods, and the steering linkage are visible. The tub is carbon fiber, the engine and transaxle castings aluminum, and the struts steel. The side pods house the oil and water tanks and radiators, the electronic modules, the exhaust plumbing, and so on.

As chassis constructors learned how to master airflow, speeds climbed. The speed boost came not only from "cleaner" designs, but from utilization of aerodynamic "downforce" that, in concert

with more sophisticated tire designs, allows ever-faster cornering. The secret is to accelerate the air moving under the car, lowering air pressure. Depending on speed, this force can be greater than the car's weight.

IndyCar's new aerodynamics regulations reduce downforce and increase drag in relation
(continued)



ILLUSTRATIONS BY JEFF RIDKEY/ART STAFF, INC.

If a team's diagnostic tests indicate a malfunction, the engine is removed entirely and replaced with another.

Oddly, the racing engines can be considered ultra-low-maintenance: No work is permitted, other than removing and checking the spark plugs; having a look-see at the cylinders via a xenon-illuminated fiber-optic bore scope, fed in through the spark-plug holes; or doing a leak-down test to

check the sealing efficiency of piston rings and valves by evaluating how well each cylinder holds air pressure. If these procedures or any of the team's diagnostic tests indicate that an engine is malfunctioning, it's removed entirely, placed in a handsome aluminum shipping container, and re-

placed—straightaway—with another that arrives in a similar container.

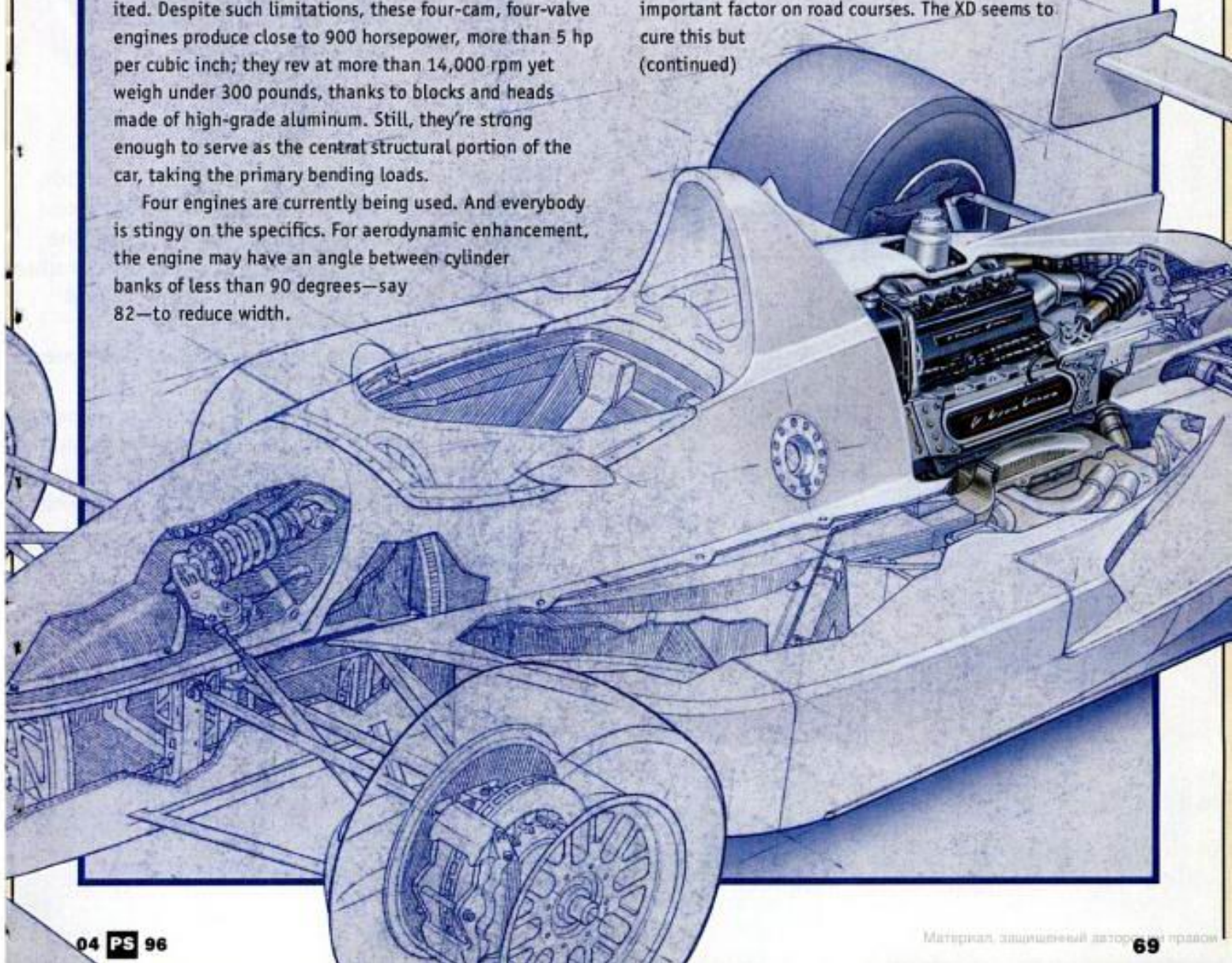
Engine engineers, who are employees of the engine suppliers, are key players. They have permanent team assignments and participate in every test and practice session, both during the season and between seasons. They do everything from fine-tuning the fuel map—the three-dimensional plot of fuel/air mixture against engine load and rpm—to adjusting the shift quality. Complex manual gearboxes can be upshifted with or without using the clutch, while keeping the accelerator floored. ▶

Engines: Turbocharged Power

INDYCAR CALLS FOR A "PURE" racing engine, up to 2.65 liters (161.6 cubic inches) and not more than eight cylinders, turbocharged. The turbocharger boost is strictly limited. Despite such limitations, these four-cam, four-valve engines produce close to 900 horsepower, more than 5 hp per cubic inch; they rev at more than 14,000-rpm yet weigh under 300 pounds, thanks to blocks and heads made of high-grade aluminum. Still, they're strong enough to serve as the central structural portion of the car, taking the primary bending loads.

Four engines are currently being used. And everybody is stingy on the specifics. For aerodynamic enhancement, the engine may have an angle between cylinder banks of less than 90 degrees—say 82—to reduce width.

The Ford/Cosworth, winner of the Manufacturers Cup in 1995, is in more cars than any other engine. The top Ford teams have the new higher-output XD version; the others get the XB. Previously, the power in these engines burst in at the top end, hurting mid-range drivability, an important factor on road courses. The XD seems to cure this but
(continued)



laps remaining to recover the lead if a pit stop became necessary. The calculation showed that nine or 10 laps under yellow would be enough to forego the stop. Team leader Chuck Sprague decided not to call Fittipaldi in.

But the track went green after only five laps. Fittipaldi held the lead, but the team's only chance was a late-race yellow. Otherwise, the data showed, he'd run out of fuel on lap 197. Sprague called Emmo in for "a splash of fuel" on lap 195. The splash took only a few seconds, but that was

fatal. Fittipaldi finished third, less than five seconds behind the winner.

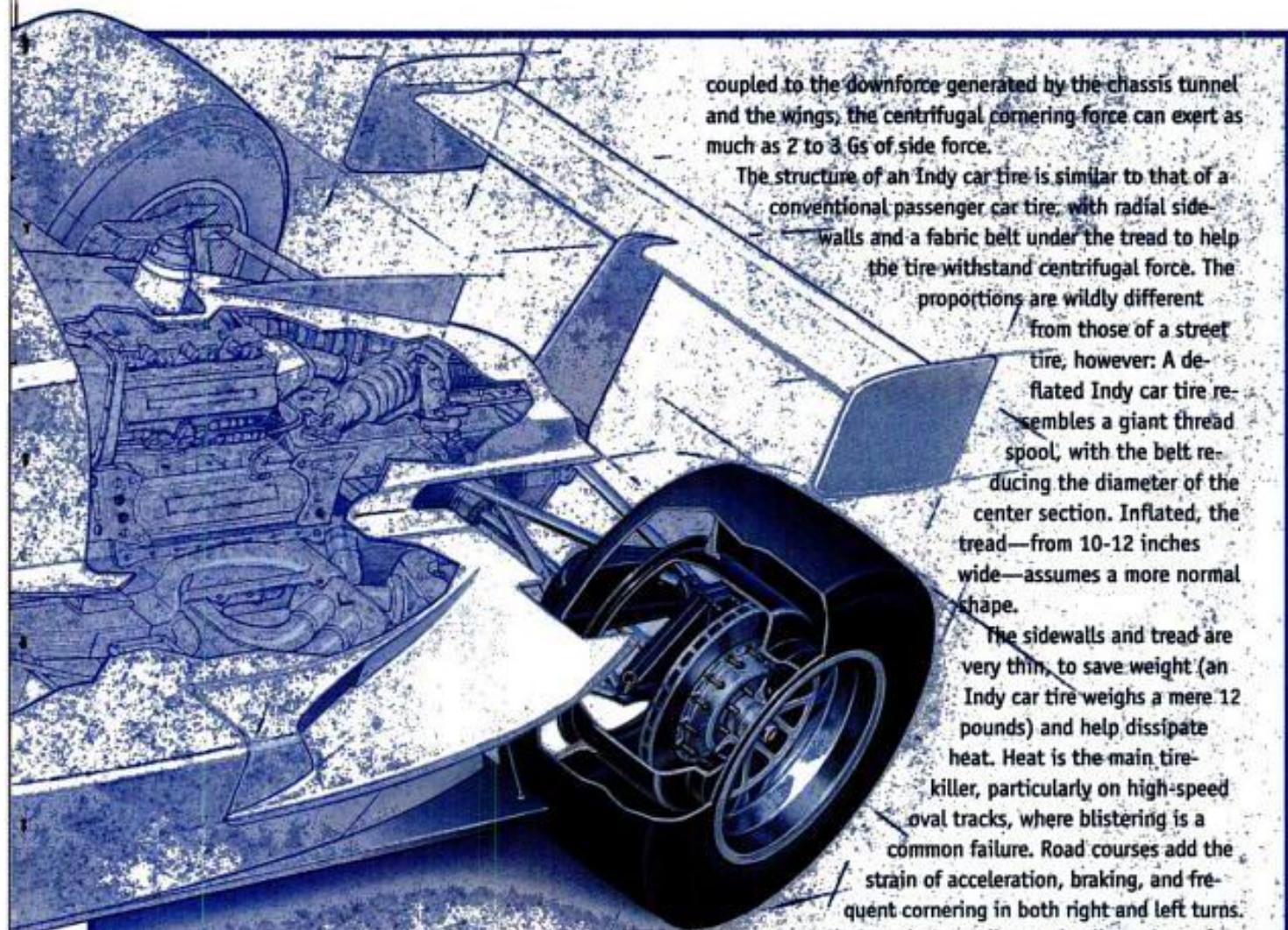
The story was replayed three weeks later, on the one-mile oval in Nazareth, Pa., with a different ending. In the later stages of another 200-lap race, Eddie Cheever, Jacques Villeneuve, and Fittipaldi were battling for the lead. Cheever's computer said he had enough fuel. The other teams had made their own calculations and were sure he didn't.

Fittipaldi, in second place, took the lead on lap 199 as Cheever slowed, his

tank empty. Fittipaldi won by .3 sec.

After the race, the emotional roller coaster was still running. As the press conference wound down, Emmo's voice became halting and tears welled in his eyes. Slowly, he found words. "I...dedicate...this win...to Ayrton." It was a tribute to friend and countryman Ayrton Senna, the brilliant Formula One driver who lost his life in a crash a year before.

Racing, for all its sophistication and technology, is still very much a human endeavor. ♦



coupled to the downforce generated by the chassis tunnel and the wings, the centrifugal cornering force can exert as much as 2 to 3 Gs of side force.

The structure of an Indy car tire is similar to that of a conventional passenger car tire, with radial sidewalls and a fabric belt under the tread to help the tire withstand centrifugal force. The proportions are wildly different from those of a street tire, however: A deflated Indy car tire resembles a giant thread spool, with the belt reducing the diameter of the center section. Inflated, the tread—from 10-12 inches wide—assumes a more normal shape.

The sidewalls and tread are very thin, to save weight (an Indy car tire weighs a mere 12 pounds) and help dissipate heat. Heat is the main tire-killer, particularly on high-speed oval tracks, where blistering is a common failure. Road courses add the strain of acceleration, braking, and frequent cornering in both right and left turns.

Indy Car rules now dictate the dimensions of the tires—in the past, only the actual wheel size was restricted. This cuts down on the possible combinations of tread width and diameter, but new materials are constantly being developed. A high proportion of carbon black and oils in the compound helps dissipate heat; softer compounds are used for the bursts of speed during qualifying.

The tires come from special engineering and manufacturing operations at Goodyear and Firestone, which supply all the tires in the race series.—A.B.S.

Tires: The Margin of Difference

AT THE START OF A RACE, AN Indy car tire has about one-eighth of an inch of tread. That's the first hint that the demands on a racing tire are considerably different from what's required of a family car's tires.

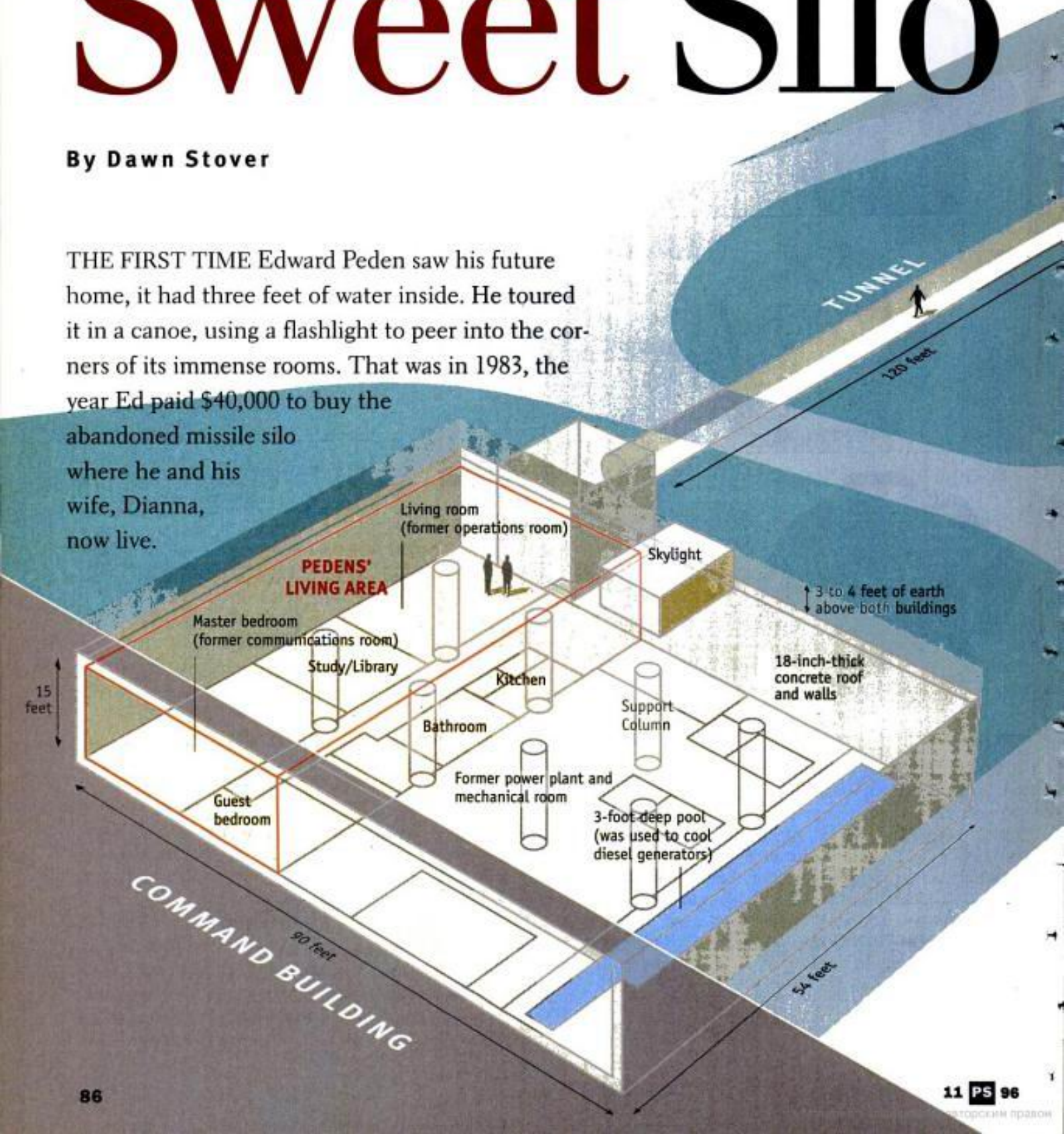
Tire technology is, in fact, second only to aerodynamics as a contributor toward the Indy cars' steadily increasing speeds. The wide tires grip the road powerfully;

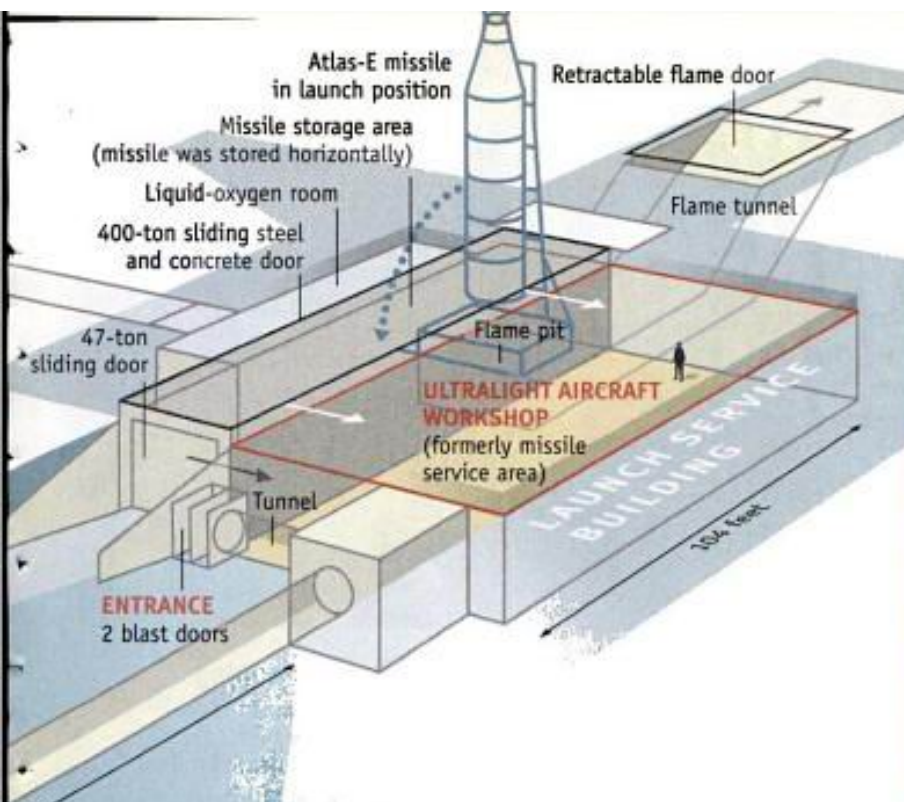
Home, Sweet Silo

What do you do with a
decommissioned missile
site? Live in it.

By Dawn Stover

THE FIRST TIME Edward Peden saw his future home, it had three feet of water inside. He toured it in a canoe, using a flashlight to peer into the corners of its immense rooms. That was in 1983, the year Ed paid \$40,000 to buy the abandoned missile silo where he and his wife, Dianna, now live.





INFOGRAPHIC BY JOHN GRIMWADE

Today's homeowner: Ed Peden displays how his missile-silo house looked in its younger, more dangerous days.



"When I saw it, I thought it was a very special structure," recalls Ed. Most of the 15,000-square-foot complex is hidden beneath Kansas prairie, on a 33.4-acre site near Dover. There, the Pedens are safe not only from nuclear attack and tornadoes, but also from big heating and cooling bills. Eighteen-inch-thick concrete walls and several feet of earth covering the roof help maintain a constant temperature inside, so the Pedens have no need for air conditioning, and use only a small wood stove for heating.

The Pedens' property is a "coffin style" Atlas-E missile site. At such sites, the giant weapon was stored on its side, and a massive concrete-and-steel door in the roof retracted so that the missile could be tilted upright for firing. Ed uses the 110-foot-long missile bay, which has a 47-ton "garage door" on one end, as a hangar for the ultralight flying wings he builds. The Pedens plan to use the 17-foot-deep "flame pit" at the other end of the building to hold several hundred thousand gallons of water for their vegetable garden.

A 120-foot-long corrugated-metal tube leads to a command building that today contains a 2,800-square-foot split-level home. In what is now his living room, Ed says, "men sat ready to fire their missile at a Russian city."

It's utterly quiet indoors, and the Pedens listen to the radio to learn about the weather outdoors. A fiberglass skylight, which has replaced a heavy cement block that once covered an equipment hatch, provides the only natural lighting to the interior.

Sprouting from the earth that covers the Peden house are two 33-foot-tall gray towers that resemble castle turrets. That's intentional. "Missile sites are the castles of this century," explains Ed, "just as the castles of Europe were built by the king for defense."



A deck extending from the Pedens' kitchen overlooks an unfinished space that once contained huge generators for the missile facility.

Ed and two partners have founded a company called Twentieth Century Castles to sell missile sites to others who dream of living in such palaces underground—or simply want a secure place to store wine bottles or to archive documents. The sites available are the Atlas series and the Titan-1s, all constructed in the 1960s. Newer facilities were destroyed when taken out of service, as required by international treaty.

Activated in 1961 and decommissioned only four years later, the Pedens' "semihardened" Atlas-E facility cost \$4 million to build. The more than two dozen of these sites that remain sell for upward of \$70,000. Peden's company also offers the "superhardened" Atlas-F, which housed its missile in a 176-foot-deep pit under eight feet of earth. Need more room? A Titan-1, with 45,000 square feet and a half mile of tubes, "is like a underground city," says Ed.

The Pedens plan to eventually build a conventional house above their missile site. That would make them the proud owners of the world's largest basement. ♦

OLYMPUS D-300L

Price: \$899

Resolution: 1,024x768

NIKON COOLPIX 300

Price: \$999

Resolution: 640x480



CANON POWERSHOT 600

Price: \$949

Resolution: 832x608



FUJIFILM DS-7

Price: \$699

Resolution: 640x480



RICOH RDC-2

Price: \$849

Resolution: 768x576



KODAK DC25

Price: \$499

Resolution: 493x373



Get the Digital Picture

Why your next camera should be digital.

PHOTOGRAPHED BY JOHN B. CARNETT

CASIO QV-100

Price: \$599
Resolution: 640x480

**EPSON PHOTOPC 500**

Price: \$499
Resolution: 640x480



DIGITAL photography is still new enough that most of us have yet to form an opinion about it, much less develop a point of view. But this hasn't stopped many film and computer buffs from agreeing on the early conventional wisdom about digital cameras—they're neat peripherals for your PC, but they're not suitable for everyday picture-taking.

The buffs are wrong: The smart money is on digital cameras—or soon will be. The latest digital cameras cost hundreds, not thousands, of dollars, and they more closely emulate the picture quality we've come to expect from film cameras. But more than anything else, digital cameras are radically redefining what photography means and what it can be.

Film and prints are not going away anytime soon. But even with improvements like the Advanced Photo System, the venerable

medium of photography as we know it is beginning to seem out of step with the way we live. In our computer-and-camcorder culture, saving pictures as digital files and watching them on TV is for millions of Americans no less practical—and in many ways a lot more appealing—than fumbling with rolls of film that must be sent off to be developed.

Paper is also terribly unforgiving. Pictures that are incorrectly framed, focused, or lighted are nonetheless committed to film and ultimately processed into prints.

The digital medium changes the rules. Still images that are captured digitally (with light-sensitive semiconductors known as a charge-coupled devices, or CCDs) can immediately be shown on a computer monitor, a TV screen, or a small liquid-crystal display (LCD) built right into the camera. And since the points of light that constitute an image are saved as a series of digital bits in

By Chris O'Malley

**SONY DSC-F1**

Price: \$849
Resolution: 640x480

**MINOLTA DIMAGE V**

Price: \$749
Resolution: 640x480

The Electric Experience

By Ron Cogan

What, exactly, are you getting into if you decide an EV1 is for you?

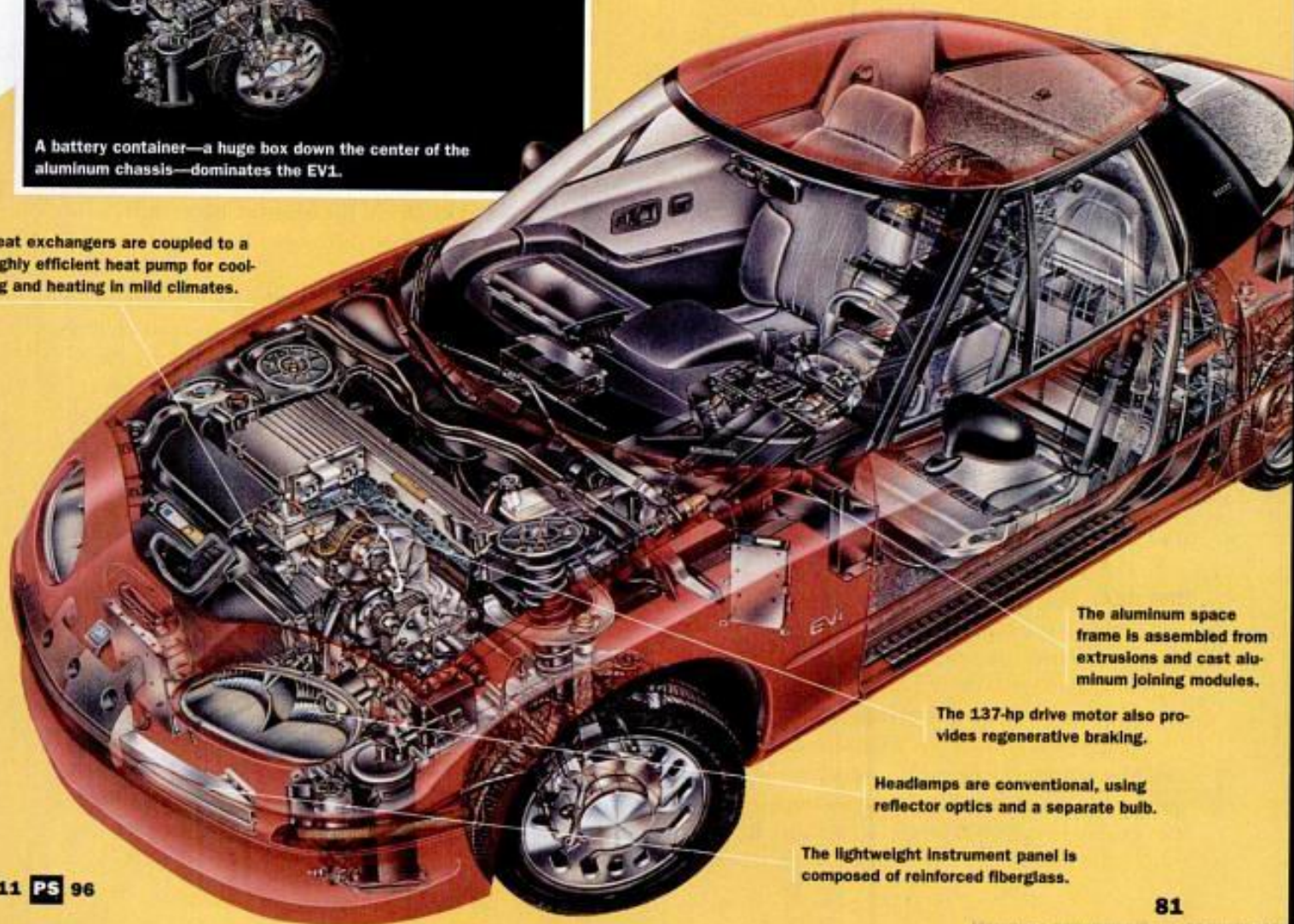
THE FIRST KICK at the high-pressure sidewalls of the ultra-low-rolling-resistance tires of GM's EV1 underscores the fact that the first electric car being marketed to the general public in decades is, well, different.

The difference is more fundamental than the mere fact that the EV1 is powered by a 137-horsepower, three-phase, AC induction electric motor that taps the stored energy of



A battery container—a huge box down the center of the aluminum chassis—dominates the EV1.

Heat exchangers are coupled to a highly efficient heat pump for cooling and heating in mild climates.



The aluminum space frame is assembled from extrusions and cast aluminum joining modules.

The 137-hp drive motor also provides regenerative braking.

Headlamps are conventional, using reflector optics and a separate bulb.

The lightweight instrument panel is composed of reinforced fiberglass.

In the event an EV1 does suffer a malfunction, the defective component will be removed and replaced by the dealer. The defective part is then sent back to GM for testing to determine why it failed—part of a continuous quality improvement effort. EV1 parts will be stocked at regional warehouses and delivered to the dealer either the same day, or the next. Battery packs will be provided via next-day delivery by Delco Propulsion Systems. Delco will also receive all end-of-use batteries from GM electric vehicles for recycling. (The batteries are 95 percent recyclable.)

When an EV1 is damaged in an accident, repair work on the aluminum structure and fiberglass body panels will be handled by an authorized Saturn dealer.

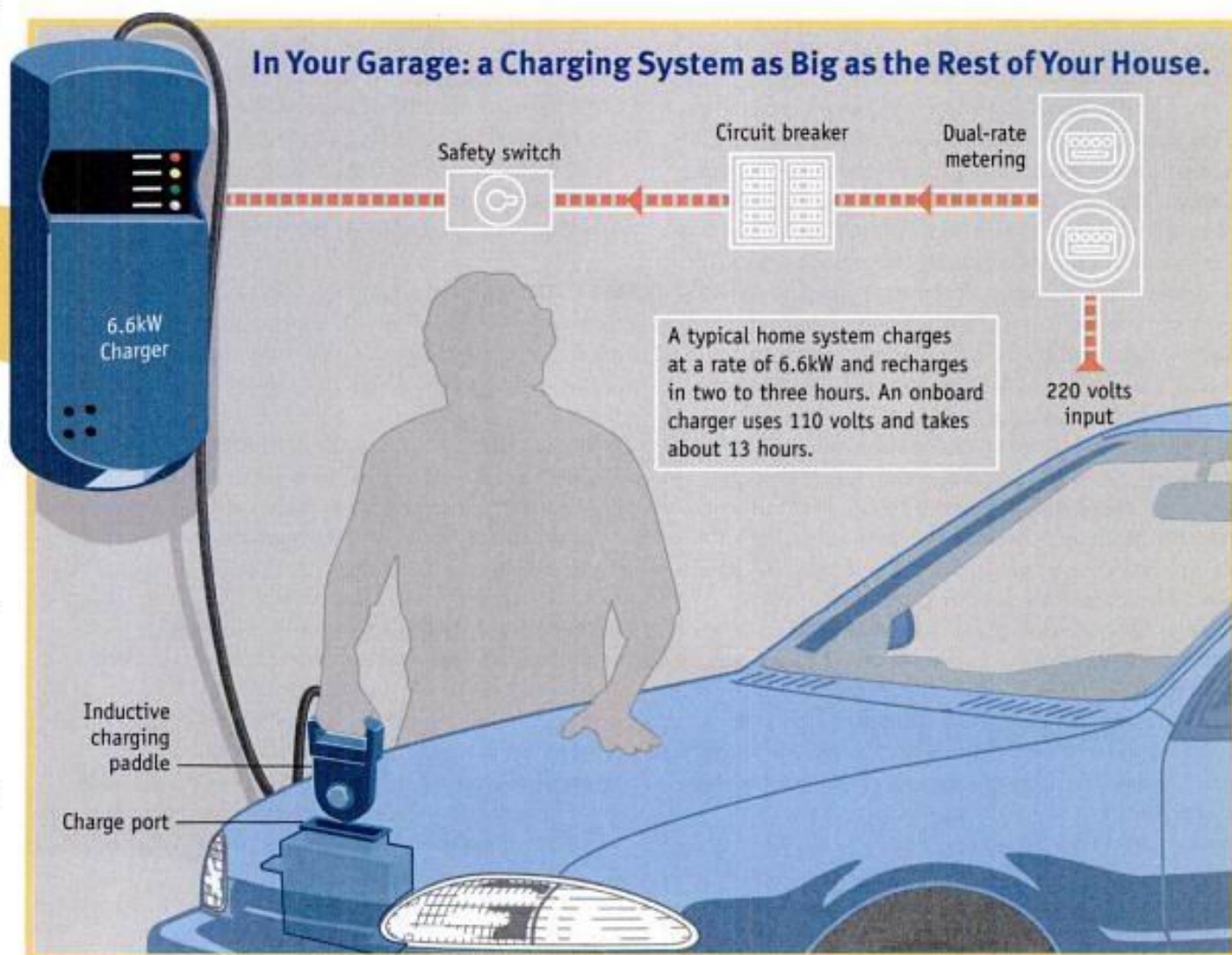
EV1 customers are encouraged to not stray too far from the car's initial marketing areas, since authorized service will not be available. While roadside service is included as part of the three-year lease, it's likely that towing charges outside of these Saturn dealers' assigned territories will be borne by the customer.

ON THE ROAD Slide behind the wheel of the EV1 and it's impossible not to notice something's missing. For starters, there's no ignition key. In its place is an elec-

tronic keypad that activates onboard systems in response to a secret code. Also gone are a few things to which we've grown accustomed, like water temperature and oil pressure gauges, and shifter selections that go beyond park, reverse, neutral, and drive. (A single-speed drive unit obviates the need for low gear and overdrive.)

Plenty of familiar features remain, though, including a Delco AM/FM/CD/cassette stereo system and such everyday accoutrements as power windows, heating and air-conditioning controls, speedometer, trip odometer, and a variety of status indicators. But some new twists are also offered, such as displays for state of charge, time to full charge, vehicle range, and passenger-compartment environment preconditioning.

Preconditioning is one of those interesting byproducts of electric vehicles that, once tried, will forever be among an EV driver's favorite features. While the EV1 is connected to a charger, it can be programmed so its innovative heat pump automatically heats or cools the car's interior to a desired temperature at a specific time...say, about 10 minutes before you're ready to head for work. If you plug in again at the work site, this same feature can also condition the interior to a comfortable temperature for your drive home.



Reinventing the Home Computer

The PC is getting a makeover. But it may turn out to be a do-over.

By Chris O'Malley

WANDER THROUGH Silicon Valley, the cradle of computing that stretches from San Jose to San Francisco, and it's not hard to see the Next Big Thing in home PCs. It's something called the Network Computer, and it's inside the gleaming glass towers of Oracle Corp. in tidy Redwood Shores. Or, wait, perhaps it's one of the many "information appliances" being developed at startup Diba Inc. inside a renovated warehouse in a gritty industrial section of Menlo Park. Or maybe it's the slick Internet television system of WebTV Networks in brainy Palo Alto. Then again, it could be the portable home-and-classroom computer being perfected at Apple Computer down in Cupertino.

Even within this narrow band of occasionally shaky ground bordered by Routes 280 and 101, that's merely an abbreviated tour of the new thinking about home computers these days. There's much more: In San Jose, engineers at Sony Electronics are weaving the company's audio and video wizardry into home PCs, while designers at Acer America experiment with new shapes and colors. Meanwhile, in Santa Clara, mighty Intel is casting the home PC as a communications hub, even as nearby Hewlett-Packard bills it as an imaging center.

What's going on here? The same thing that's happening in the labs at Compaq, Gateway, IBM, Microsoft, Philips, Thomson, and countless smaller companies, here and abroad. They are reinventing the home computer, and our most basic notions about PCs—what they look like, what they do, how they do it, where they do it, how much they cost, and who buys them—are up for grabs. After years of simply turning up the megahertz and megabytes for

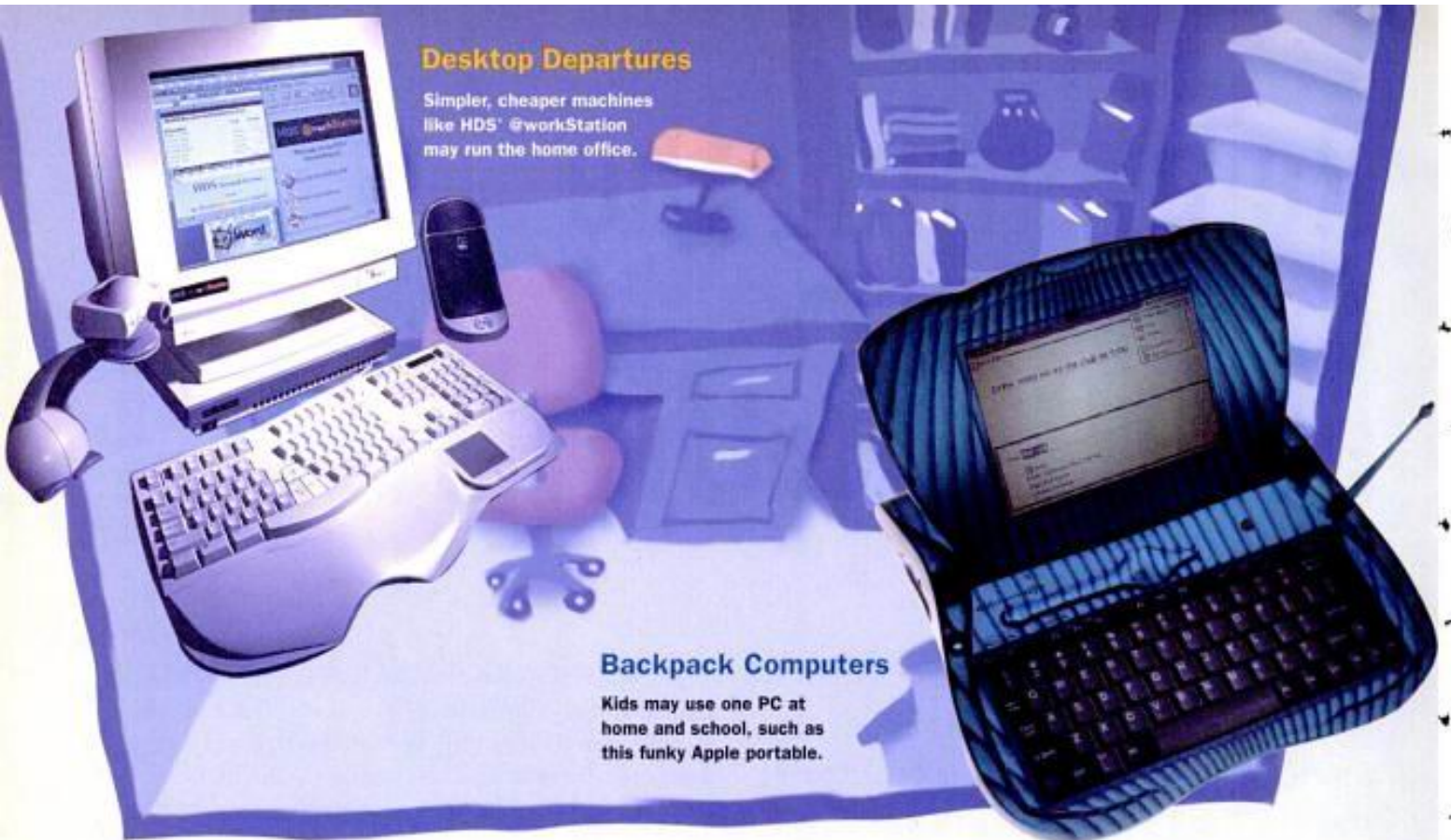
Tapping the Network

The "network computer," or NC, dreamed up by Oracle can take many forms, including portables.

Java Espresso

Someday, Java terminals like this Diba concept may bring the Internet to you.

ILLUSTRATION BY ELIZABETH BRANDT



Desktop Departures

Simpler, cheaper machines like HDS' @workStation may run the home office.

Backpack Computers

Kids may use one PC at home and school, such as this funky Apple portable.

business customers and then passing the same boxes onto consumers, the computer and electronics companies of the world are endeavoring to build a home PC that can rival the telephone and television for usefulness and ubiquity.

Take your mark and get ready—the Race to Build the Great Home Computer is on. But this race has few rules and no clearly marked finish line. “The whole notion of a home computer is changing dramatically,” says Andy Hertzfeld, the software wizard who helped create the original Macintosh—once touted as “the computer for the rest of us”—and who now toils at General Magic in Sunnyvale, California. “Computers in the home are going to be so diverse, and so pervasive, it’ll almost be too broad a category to call them home computers.”

On the surface, today’s multimedia home computer might seem an odd choice for an overhaul—or an outright replacement. Computers get more versatile every year and, in time-adjusted dollars if not actual price, they are less expensive than ever. Home PCs have proven tempting enough that roughly a third of U.S. households have invested in one, and overall PC sales are still rising.

Yet, many both inside and outside the computer industry see the glass as two-thirds empty, with little prospect of filling. The “early adopters” and well-to-do families may have home PCs, they argue, but computers as we know them are still far too complex and costly for the less tolerant, less affluent masses. More intractably, many Americans still don’t see the need for a PC in their homes. And many of the families who’ve already bought in aren’t thrilled with their cranky, quickly outdated machines.

“The home PC has basically been a failure,” asserts

Paul Saffo, a director at the Institute for the Future, a digital think tank in Menlo Park. “It’s been a sometimes useful failure, but nonetheless an artifact of office processing machines that do not present a very compelling experience for consumers.” And that, he notes, is the lesson in all this for anyone who wants to bring computing home: “It’s the experience, stupid.”

How do you make a simpler, cheaper, stabler machine that delivers a more inviting experience? There is little consensus, but many of the disparate visions can be broadly categorized into five types of future PCs:

NETWORK COMPUTERS

Why buy a costly, complicated PC of your own when there are powerful computers outside your home that can supply the software, processing power, and storage space? That’s the basic premise of the so-called Network Computer, or NC. Essentially, NCs are compact computers—some will be as small as TV set-top boxes—that rely on a link to a remote “server” computer to run everyday programs such as word processors and games, store data files, and surf the Internet. Many NCs will use the TV as the display, but they could also be coupled with a built-in screen or computer monitor.

There are several potential advantages to owning an NC rather than a PC. The most alluring may be its low cost. The NC has a central processor and some of the input-output functions of a PC, but not its large amount of memory, disk drives, or audio and video processing gear. In fact, several companies are working on putting nearly the entire set of NC functions onto a single chip. Conse-

quently, homebound NCs are expected to cost between \$300 and \$700. Other pluses: There's no internal hardware to install or configure, software could be automatically updated for you, and because all files are stored on the network, you might never lose data again. Moreover, freed from Windows and Mac conventions, NC service providers and software programmers have another shot at making computers easy to use. "We know that computers are still way too complicated for many consumers," says Dan Stack, a manager in Oracle's NC division. "If PCs cost \$1.50, my parents still probably wouldn't buy one."

But significant drawbacks will arise, too. Chief among them is the fact that the data pipeline into most homes—the telephone line—is a narrow one, which may result in more waiting than PC owners are accustomed to. And though cable and satellite alternatives are on the horizon, that pipeline may not change for years. There would also be as-yet-unspecified monthly service bills to pay (for server access and storage). For a while, at least, your software choices will likely be quite limited, too.

The NC concept was pioneered by Oracle, and the NC "reference profile" being used to build these systems was influenced and endorsed by Apple, IBM, Netscape, and Sun Microsystems. Several other notables, including Digital Equipment and NEC, are backing the effort as well. Oracle claims more than 60 companies are working on NC devices or services overall. The first wave of these NC-logo devices is expected to show up later this year or early in 1997.

TV COMPUTERS

Though they bear some similarity to NCs, computer-and-TV marriages—which have only recently begun tying the knot—generally do not attempt to redefine the PC or how we run software such as word processors. Rather, they fall into three subcategories that each seek to leverage the strengths of computers and TVs: Internet access devices, online game players, and full-blown PC-TV combinations.

Internet access devices, such as the set-top box from WebTV Networks that Sony and Philips (with its Magnavox brand) are selling under their own names, have a fairly narrow focus: They enable you to log onto the World Wide Web and send or receive e-mail via your TV and a phone line. [See "Web TV," October.] Most of the early devices will be in the form of set-top boxes, though Zenith Electronics and eventually others will put the circuitry inside TV sets, requiring only a phone line hookup. Though obviously limited in function, these Web browsing additions cost only \$200 to \$500—far less than even a basic PC with a modem.

Online game players attempt to mix the features of video games and CD-ROM discs with the appeal of the Web, again via your TV. Some in this new breed are, in fact, video game players. Sega's Saturn machine has a NetLink option for Web access, for example, and both Sony and Nintendo plan similar options for their systems.

Kitchen Work

Diba's under-the-counter CD-ROM player for recipes and nutrition.

Mail Call

A phone and e-mail station from Diba with a folding keyboard and LCD.

Internet TV

A Diba set-top "slice" modem for Web browsing via the TV.

NC Service

A set-top box may bring full-fledged computing to your TV.

THE WHAT'S NEW MAGAZINE

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NEXT-GENERATION SPYSATS

Inside the
Newest **KH-11**

**Stealth
WARSHIP**

**Report Card
for GM's
ELECTRIC
CAR**

**Sony's
Chief
Maps the
DIGITAL
FUTURE**

**NEW FUEL
BENEATH
THE SEA**

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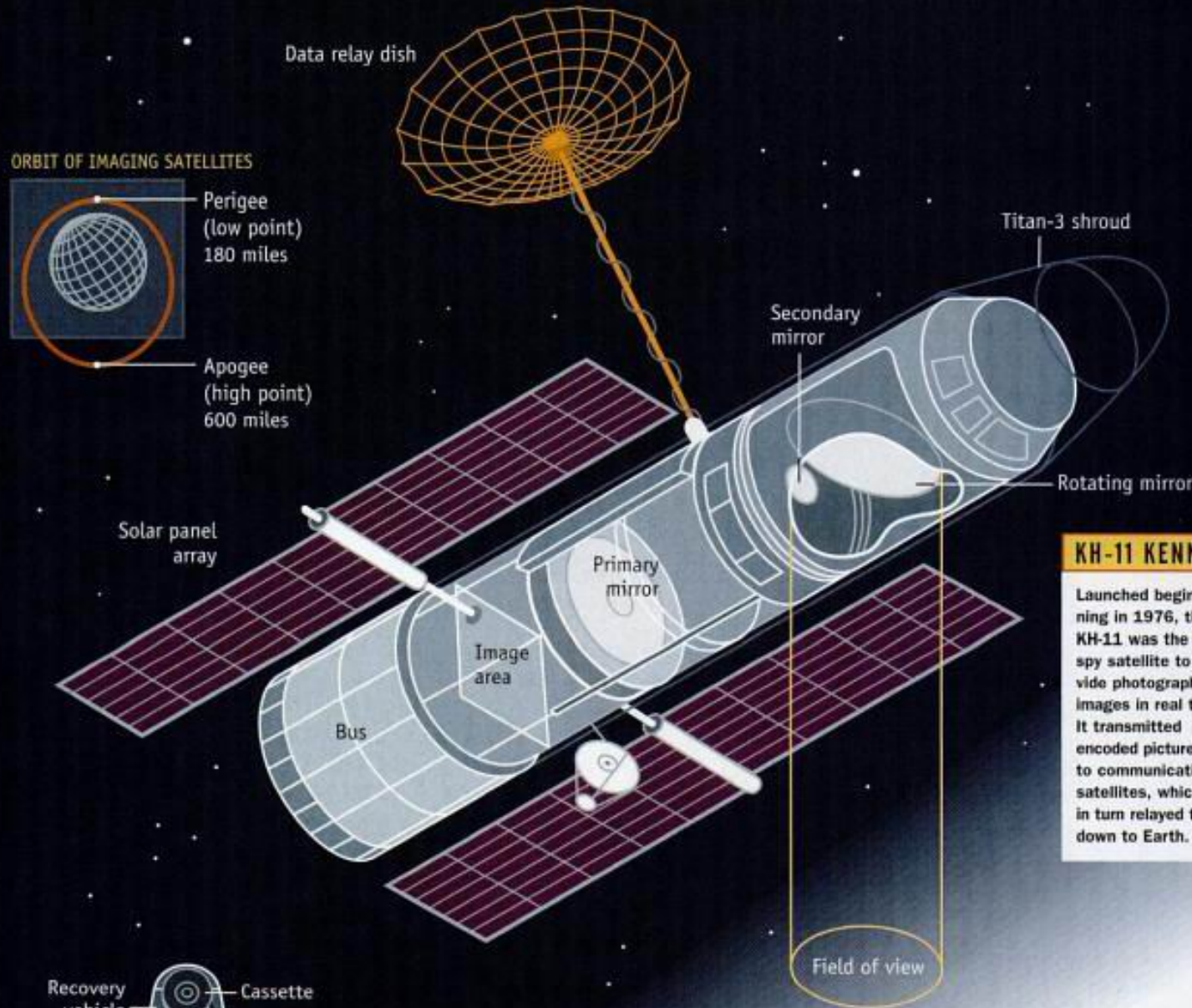
CELEBRATING

125

YEARS

OF POPULAR SCIENCE

This Month: Landmark Discoveries in Science & Technology



KH-11 KENNAN

Launched beginning in 1976, the KH-11 was the first spy satellite to provide photographic images in real time. It transmitted encoded pictures up to communications satellites, which in turn relayed them down to Earth.

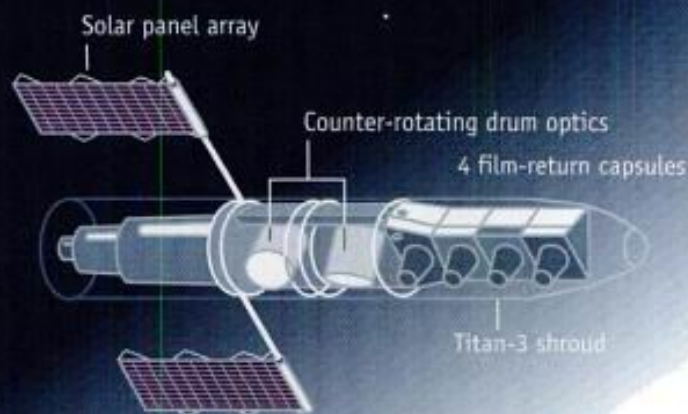
KH-4 CORONA

America's first spy satellite, Corona ejected film capsules that were retrieved in mid-air by a cargo plane. Corona took more than 800,000 photographs between 1960 and 1972. The program was declassified in 1995.

Your tax dollars pay for the world's most expensive snapshots.

INFOGRAPHICS BY
CHARLES VICK & ALEX REARDON





KH-9 BIG BIRD

Big Bird's primary mission was to capture wide-field images, but it was also able to take high-resolution surveillance images. First launched in 1971, it was instrumental in monitoring Soviet missile tests.

ON DECEMBER 20, 1996, a Titan rocket as tall as a 20-story building lifted off from Vandenberg Air Force Base in California, and thundered out over the Pacific Ocean and into space. It was carrying one of the U.S. government's biggest secrets.

The Titan was built for only one purpose: to place intelligence-gathering satellites in orbit. The importance and the complexity of these satellites can be gauged by what they cost: as much as \$800 million or more apiece, more than a B-2 bomber. But while a military aircraft will serve for decades, a spy satellite does well to remain fully operational for five years. The Pentagon spends well over a billion dollars annually just to maintain its constellation of about 20 intelligence satellites.

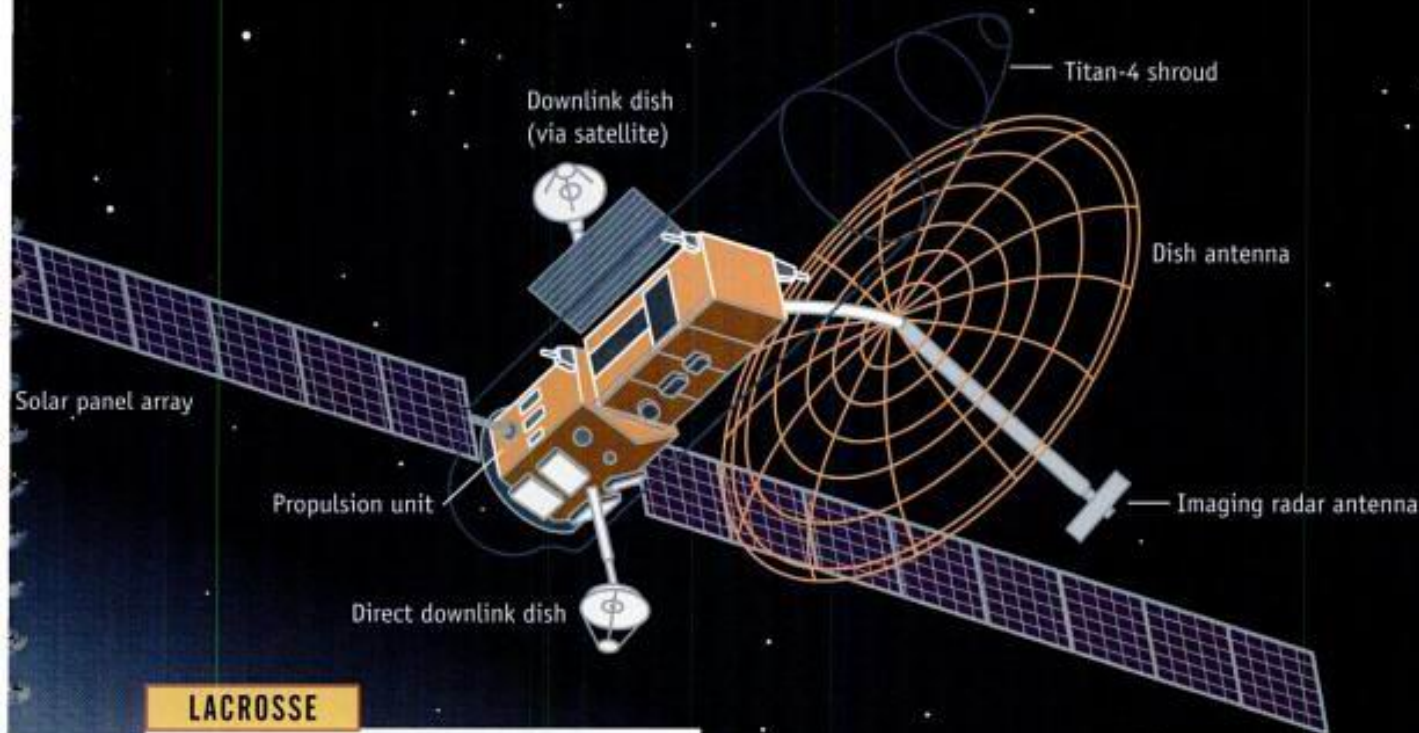
The world of spy satellites has an Alice-in-Wonderland quality. The existence of the National Reconnaissance Office, the Pentagon agency responsible for the development and operation of all intelligence satellites, was not even acknowledged until a few years ago. Now the NRO has its own Web site. But even the most basic information about any spy satellite launched in the last 25 years remains secret. The NRO will not reveal the names of any of its spy satellites, what the satellites are designed to do, how many have been built, who built them, or how much they cost the taxpayers who foot the bill.

SPIES IN THE SKY

By Bill Sweetman

Government officials are loath even to utter the words "reconnaissance satellite." Obscure phrases such as "national technical means" are more career-enhancing. And yet everyone knows that spy satellites exist. The launch of a massive Titan rocket is about as inconspicuous as a heavy-metal gig in a Trappist monastery.

The whole world knows how good the images from a reconnaissance satellite can be, because a Navy intelligence analyst named Samuel Morison gave satellite photographs of the Soviet Union's first full-size nuclear-powered aircraft carrier, under construction at a Black Sea port, to *Jane's Defence Review* magazine in 1984. The im-



LACROSSE

First launched in 1988, the Lacrosse uses radar to see at night, and through cloud cover. Radar data can be enhanced by computers to make it easier to see shapes, even of objects hidden beneath soil, sand, or snow.

wait until the next film bucket was full, or to bring a capsule down immediately and use up a quarter of the spacecraft's capacity. The end of this dilemma came in 1976, with the launch of the first KH-11 Kennan, one of the most remarkable military devices in history.

The KH-11 is a cylinder, more than 40 feet long and 10 feet in diameter for most of its length. It weighs about 18 tons, fully fueled, and is made in two main sections. A short, slightly wider section called the "bus" contains the main rocket engine, which puts the satellite into its final orbit, and small side thrusters that steer the craft. The bus carries the fuel tanks and the flight control system.

The other major section is the camera. Running the length of the satellite is a hollow tube containing a folded optical system, like a reflector telescope or a mirror-type telephoto lens, with a primary mirror 12 feet in diameter. Made of a thermally stable glass, the mirror is cast in the form of a honeycomb, to provide rigidity and strength without the weight of a solid mirror, and is ground to an accuracy of less than one-quarter the wavelength of light.

Light from the subject enters the camera through a port on the satellite's side, striking a flat, oblique mirror



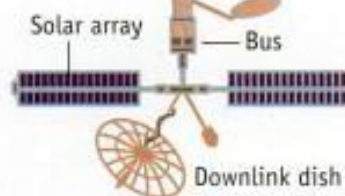
AFP-731

Launched in 1990, the AFP-731 is believed to be among the first in an improved series of KH-11s, called KH-12. The military equivalent of the Hubble Space Telescope, this satellite is more maneuverable, stealthier, and has better low-light capabilities than its predecessors.

that reflects it roughly 90 degrees onto the primary mirror. The oblique mirror rotates slightly during the exposure to compensate for the satellite's motion as it travels around the Earth at 17,500 mph.

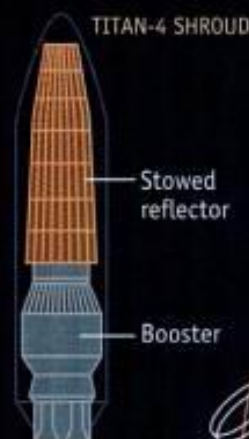
The primary mirror focuses the image onto a smaller, movable mirror, which scans the image across the spacecraft's primary sensor: an array of charge-coupled devices (CCDs), similar to the CCDs in a home video camera. The CCD was the breakthrough that made the KH-11 possible, because it was the first electronic device that could provide resolution approaching that of film. The elec-

328-foot
diameter
reflector



VORTEX

From a geosynchronous orbit, SIGINT (signals intelligence) satellites such as Vortex and Double Magnum listen in on electronic communications, including missile telemetry that can be used to verify treaty compliance.



tronically recorded image is then encoded and transmitted to Earth via a communications satellite.

How good is the camera's resolution? Both optical theory and anecdotal evidence suggest that the rumor about "reading license plates in the Kremlin parking lot" isn't far from the truth. Arms treaties in the Cold War era set limits on missile improvements that would have changed the diameter of a missile by barely three inches—and since satellites are the means by which the treaties are verified, it has to be assumed that the satellites could see such a change. Ponder that the next time you're sunbathing in the privacy of your own backyard.

An imaging satellite is launched into a "sun-synchronous" orbit, slightly offset from a purely polar orbit. As the satellite spins around the poles, Earth rotates beneath its track. The normal orbit is elliptical, with an apogee (high point) of about 600 miles and a perigee (closest approach) of 180 miles. The perigee is located over the middle and upper latitudes, where most of the important intelligence targets are found; the satellite passes close to these targets, and then rises to its apogee to reduce drag and conserve fuel.

The United States usually flies two KH-11s at a time. Their orbits are staggered, so that a satellite passes

within imaging range of any point on Earth once every two days.

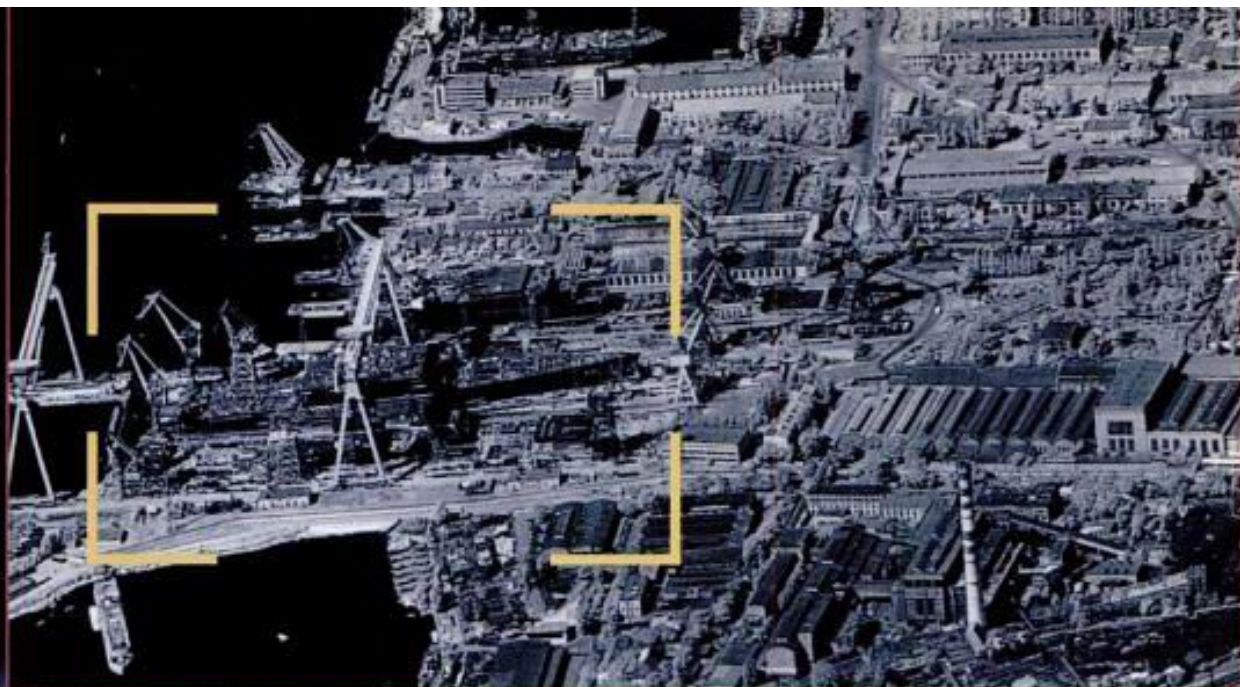
Some orbits are mysterious. Among satellite trackers, the real head-scratcher is the satellite known as AFP-731. Soon after the space shuttle *Discovery* launched the satellite in February 1990, the Russian government announced that it had detected debris where the AFP-731 should have been, giving the impression that it had broken up. But in October 1990, Molczan traced an unidentified-object report back to AFP-731's last known orbit—the errant spysat had been found, in an unusual 500-mile-high circular orbit. One month later, it vanished again.

Observers say that AFP-731 could hardly have failed on the eve of the Gulf War without some word leaking out. Pike and others speculate that it may have been the test bed for a more survivable "warfighting" satellite that uses a light-absorbing shroud to shield itself from view. Satellite trackers also speculate that AFP-731 may have been propelled into a different orbit, with its apogee over the middle latitudes, to give it more time within sight of the Gulf theater at the expense of resolution.

AFP-731 is believed to be the first of a new series of satellites known as Improved KH-11 or KH-12. In the late 1970s, the NRO intended to replace the KH-11 with a much larger satellite that would be launched by the shuttle. After the Challenger disaster, the NRO and Air Force canceled most of their shuttle launches and ordered more Titans. AFP-731 flew on the shuttle, but later satellites in the series were redesigned to fit on the Titan.

These large imaging satellites are produced at such a low rate that they are custom-built, one at a time. No satellite is exactly like its immediate predecessor, and each incorporates the latest technology. Since the first KH-11s were introduced, the satellites have probably been im-

Shot July 1984 by a KH-11 satellite from a distance of 504 miles, this photo shows the Soviet Union's first full-size nuclear aircraft carrier under construction at a Black Sea shipyard.



HOW GOOD IS THE RESOLUTION? THE RUMOR ABOUT "READING LICENSE PLATES IN THE KREMLIN PARKING LOT" MAY NOT BE FAR FROM THE TRUTH.

proved in many ways. For example, experts like Pike and Vick believe that the newer satellites can see better under moonlight or starlight by using the latest electronics to increase the amplification on the CCDs.

The KH-11s are not the only imaging satellites developed by the NRO. In 1983, the NRO started work on a reconnaissance satellite that, unlike the KH-11, would work on the darkest night or against intelligence targets covered by clouds. Code-named Lacrosse, it was designed to be launched on the shuttle, and carried a large antenna for a synthetic aperture radar (SAR).

A radar's resolution is limited by the aperture or size of its antenna. SAR gets around this problem by adding together a series of radar snapshots to produce a detailed map of stationary objects. The effect is the same as if the satellite had an immense antenna.

Two Lacrosse satellites are in orbit, and both are relatively old. The first was launched by a space shuttle in December 1988, and the second by a Titan rocket in early 1991. According to recent reports, at least one Lacrosse is still operational, and was used to detect craters made by cruise missile attacks on Iraq in September 1996. A new version of the satellite, with a higher-resolution radar, is believed to be under development.

The NRO has also developed and launched a series of signals intelligence (SIGINT) satellites. Although these "electronic eavesdropping" satellites are not as large or spectacular as the KH-11 and Lacrosse imaging space-

craft, they can provide valuable information about the intentions and capabilities of a foreign power.

The SIGINT satellites are smaller than the imaging spacecraft because they are placed in a geostationary orbit, 22,300 miles above the equator, so that they hover over one point on the earth. The Titan booster launches not only the satellite but also a Centaur upper-stage rocket to carry the satellite to its lofty orbit.

Known by a long series of code names—including Aquacade, Jumpseat, Mentor, and Magnum—SIGINT satellites have steadily grown in size, as is clearly evident from the size of the boosters needed to put them in orbit, as well as the size of the payload shrouds. More than likely, the latest versions of these satellites are the biggest because they have the largest antennas, the better to listen in on weak military communications.

Analysts believe that most SIGINT satellites have circular "wrap-rib" antennas. Stowed in the shroud, the antenna resembles a metal-mesh umbrella, except that the spring-loaded ribs spiral around its body. Later SIGINT satellites, such as the Double Magnum, may have switched to a new "catenary" antenna, as much as 500 feet in diameter, held in tension inside a folding ring truss. The first Double Magnum was probably launched in 1994.

The Navy has been the driving force behind a final distinctive class of reconnaissance satellites: the Navy Ocean Surveillance System (NOSS). A NOSS launch

SECTION THROUGH TITAN-4 SHROUD

Satellite 1

Satellite 2

Satellite 3

TRIPLER

Navy Ocean Surveillance System (NOSS) satellites, such as Triplet, are launched three at a time. They eavesdrop on military transmissions, comparing the arrival time of these signals to determine the location of their source.

Titan-4 shroud

Communications dish

Bus

Infrared camera system

Rotating mirror

Laser communications

3 satellites orbit within line-of-sight of each other



Solar array

Sizing Up the Spysat Constellation

Today's spy satellites are much larger than the 1960s-vintage Corona.



puts not just one satellite into orbit, but three identical craft that orbit within sight of each other. The most likely reason is that the satellites carry their own SIGINT systems, to detect stray electronic emissions from a hostile fleet of ships. By comparing the time of arrival of a signal at each of the three satellites, the system can pinpoint the source's position in the ocean.

Despite their enormous cost, intelligence satellites received mixed reviews in the Gulf War. Theater commanders who had little previous experience with satellites were both amazed by the quality of the imagery, and frustrated by the time it took to obtain it.

This should not have been surprising, because the satellites were designed to gather intelligence, not to search for targets on the fly. The satellites' telescopes have a long focal length and a proportionally narrow field of view. Because there are few of them, they pass within range of a target infrequently—and if the weather is bad or another image request has higher priority, the commander must wait for the next pass.

At a post-war conference, retired Air Force Chief of Staff General Michael Dugan commented that spy satellites had failed to support the combat units "because they were scheduled by God and Kepler." Bernard Randolph, a former commander of the Air Force's Space Systems Division, then retorted that the satellites were "scheduled by some weenie in Washington, which is why they didn't support the troops."

Since the Gulf War, a secret battle has been fought in Washington, as some theater and tactical commanders, along with some members of Congress, have pushed the NRO to develop smaller spy satellites that could be produced at more economical rates. These satellites would borrow components and technology from commercial spacecraft, and would not have to be launched by the specially built Titan. This would not only save money, but would also make it possible to orbit additional or replacement satellites on short notice.

The NRO argued until this year that smaller spacecraft could not match the resolution of the KH-11, and that a large constellation of small satellites would cost more than a few large spacecraft. In 1994, the NRO gained approval for a new series of large satellites, and more Titans were ordered to launch them. The next-generation satellites appear to be even bigger than those of today, because the new Titan 4Bs have been designed to loft heavier payloads than their predecessors. The first of the new satellites, which may carry both optical and radar sensors, is likely to fly in the year 2000, because that is when the first heavyweight, low-orbit Titan 4B is due to be launched from Vandenberg.

In 1996, however, the NRO reversed its position and decided that future satellites could be as little as 20 to 25 percent of the mass of today's photo and radar imaging spacecraft—that is, with a launch weight of around 6,000 to 7,000 pounds. The next step is likely to be the development of an operational prototype for a small satellite.

Meanwhile, enough Titan 4Bs have been ordered to launch heavy spacecraft until the year 2008, so their downsized replacements need not be in service before 2010 at the earliest. It will be a long time before the last of the Cold War giants ends its useful life and plunges flaming into the atmosphere. ♦

Super Touring

These family cars race with plenty of attitude.

By Tony Swan

HERE'S A NOVEL IDEA: a stock car racing series that actually uses stock cars. More or less.

Now in its second season, the new North American Super Touring Championship is organized around mid-size sedans like the Dodge Stratus and Honda Accord, and operates as a support series for the PPG CART World Series on temporary street and permanent road-racing circuits.

Like NASCAR's Winston Cup Championship and the Sports Car Club of America Trans-Am series, the Super Touring cars in this racing circuit look very much like their production counterparts.

Unlike NASCAR's tube-framed Ford Thunderbirds, Chevy Monte Carlos, and Pontiac Grand Prix, however, the Super Touring cars are actually based on production chassis and engines, up to 2.0 liters displacement. Nearly every manufacturer on Earth offers an engine that meets this specification, and the series rules permit some mix and match on this score.

For example, the two-car PacWest Dodge Stratus team, which is backed by Chrysler, uses race-prepped versions of the 2.0-liter DOHC 16-valve Neon engine, which isn't offered in the production Stratus. In production tune, this engine is rated at 150 horsepower, while the racing version generates almost 300.

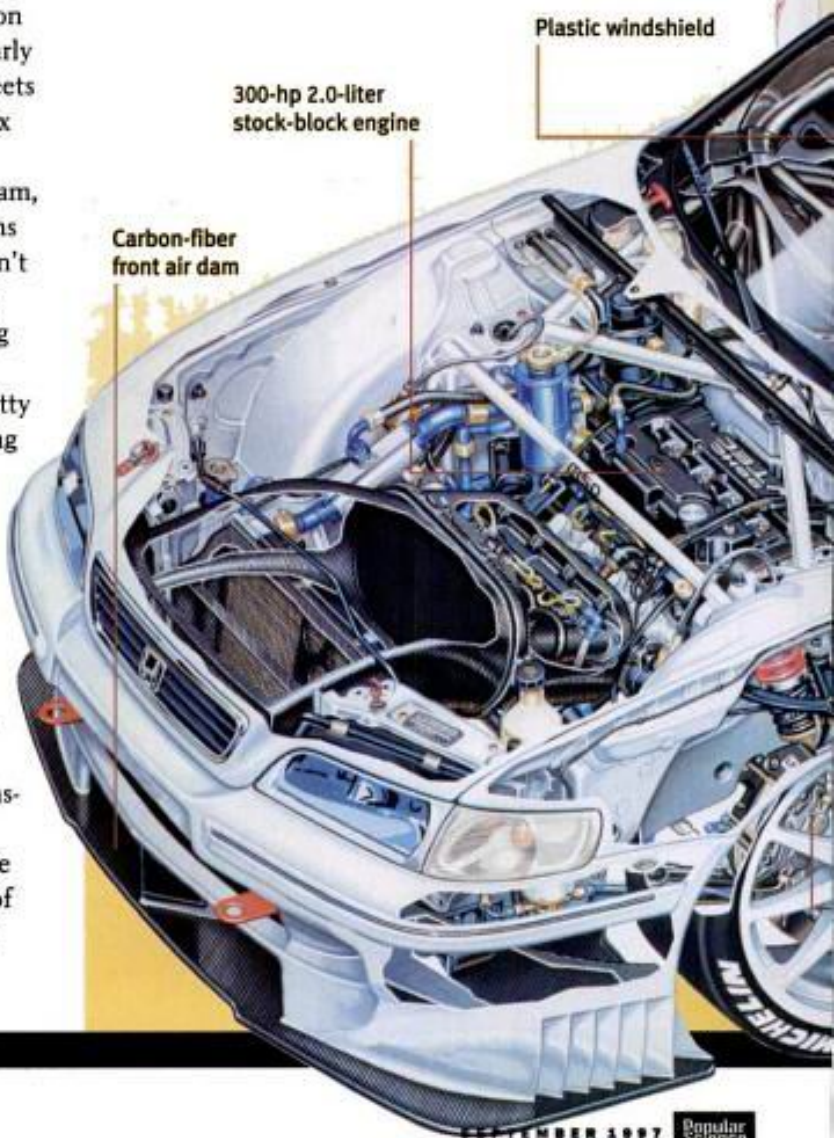
Although Super Touring engine builders can do pretty much as they please with engine components, including a dry sump lubrication system, development begins with the stock engine block and heads, and the stock crankshaft orientation. Peak rpm is electronically limited to 8,500, to preserve engines and thus cut costs. More significant, the cars must run with catalytic converters and use Texaco CleanSystem 94 unleaded gasoline—an impressive feat in an engine with a compression ratio of 12.2:1. (For contrast, the compression ratio in a stock Neon twin-cam engine is 9.6:1.)

Similarly, the builders have lots of latitude with chassis and powertrain components but must start with a stock body shell and floorpan. Though the interiors are completely gutted, the cars must also retain portions of the stock dashboard, though most teams substitute an

LCD screen with digitized information for the standard instrument array. In addition to basic information like coolant temperature and rpm, the readout can include more sophisticated data like vehicle ride height, brake rotor temperatures, and lap times.

Vehicle ride height is another readily visible difference between a Super Touring car and its stock counterparts. Most of the touring cars have about 1.5 inches between the front spoiler and the pavement, compared to 6 inches or so for a stock car, even though the cars ride on 19-inch wheels mounted with series-spec Michelin Pilot racing tires.

Transmissions are close-ratio six-speed manuals with sequential shifting—push the lever forward for downshifts,



pull back for upshifts, just like a motorcycle. The cars are equipped with clutches, used mainly for the standing starts, but the drivers don't use the clutch for shifting.

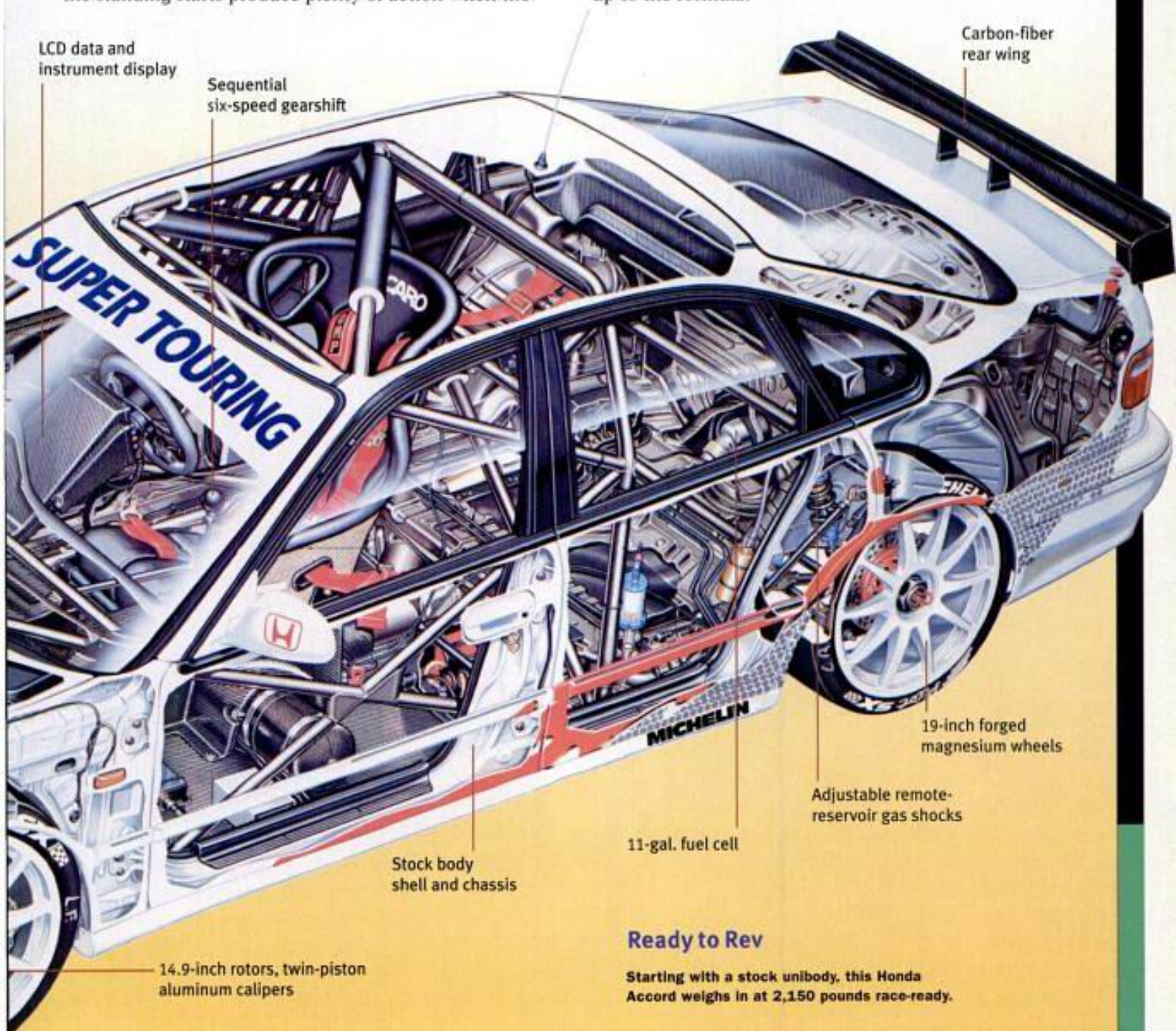
Ready to roll, a front-drive Super Tourer like a Honda Accord or Stratus has to weigh at least 2,150 pounds. Such rear-drive cars as a BMW 318 have a 55-pound weight handicap. Other cars showing up on North American starting grids include Ford Mondeos (the European version of the Ford Contour) and Toyota Camrys.

Although 300 hp doesn't sound like much compared to the 600-plus of a Winston Cup car, it's enough to produce 5-second 0-to-60 times in a 2,150-pound car. And the standing starts produce plenty of action when the

pack snarls into the first turn at the outset of a 30-minute sprint race.

The Super Touring Championship is closely patterned on the highly popular British Touring Car Championship, the progenitor of 23 similar championships around the world. It's not bargain-basement racing. A race-ready car represents an investment of at least \$150,000. But it provides some of the best slam-bang, take-no-prisoners racing on earth. A 30-minute sprint doesn't afford any room for patience.

Although still in its infancy, with relatively small fields, the North American races have so far lived up to the formula.

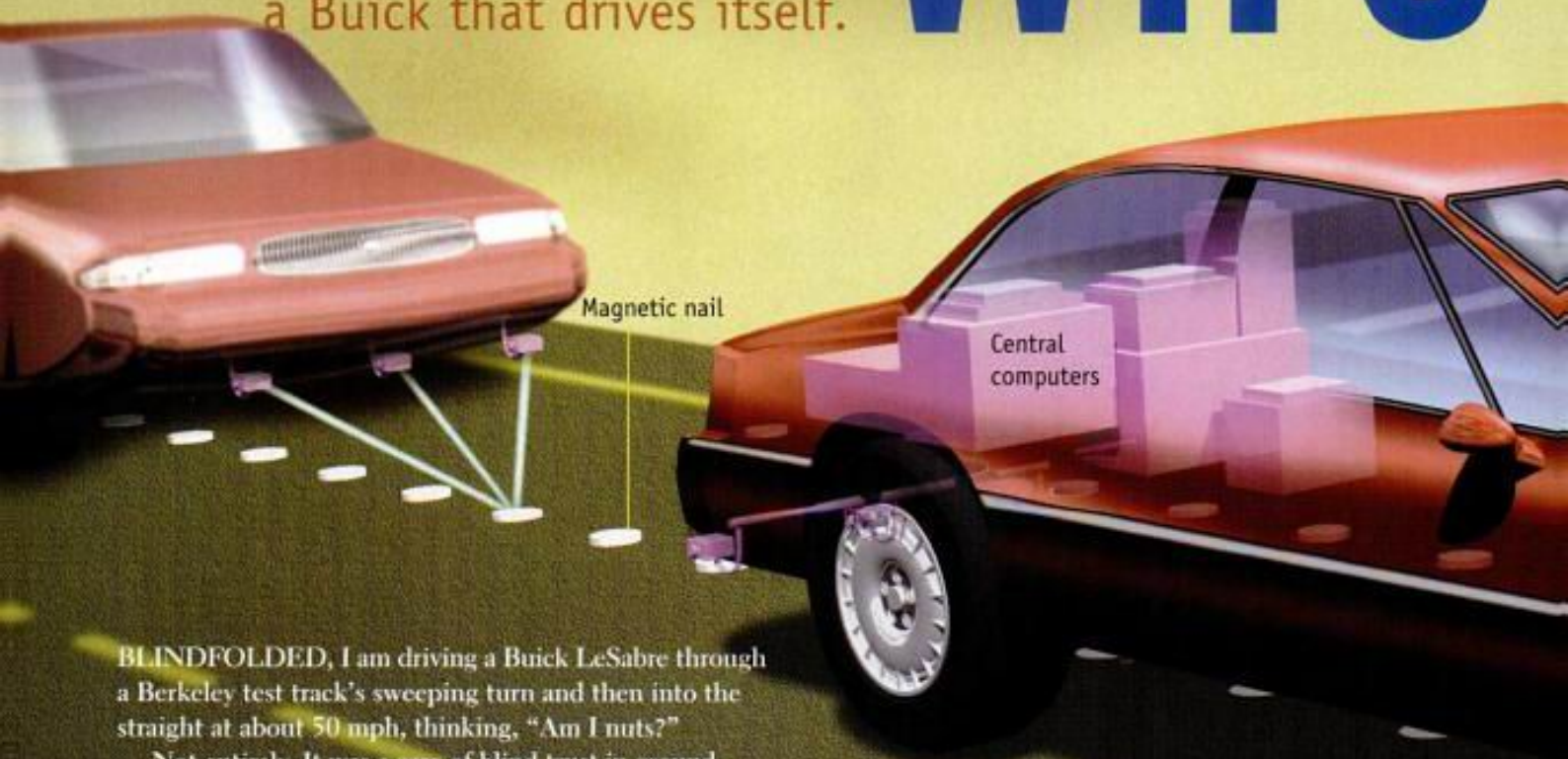


Ready to Rev

Starting with a stock unibody, this Honda Accord weighs in at 2,150 pounds race-ready.

Drive by Wire

Testing an automated highway, we buckle up in a Buick that drives itself.



BLINDFOLDED, I am driving a Buick LeSabre through a Berkeley test track's sweeping turn and then into the straight at about 50 mph, thinking, "Am I nuts?"

Not entirely. It was a case of blind trust in groundbreaking automated highway technology. This was the first public automated highway demonstration by Buick and a brain trust of University of California, Berkeley,

researchers aimed at demonstrating that automated vehicle control actually works.

By Ron Cogan

For the test, orange cones delineating the course were spaced to allow a scant 12 inches on both sides of the LeSabre's fenders. Yet in both blindfolded and eyes-open-but-hands-off rides, the car effortlessly found its center through turns and straightaways at speeds ranging from 25 to 55 mph. Not a cone was displaced. Which is more than can be said of my later attempt to catch the intelligent test car in a conventional LeSabre during a man versus computer-controlled machine matchup. Chasing

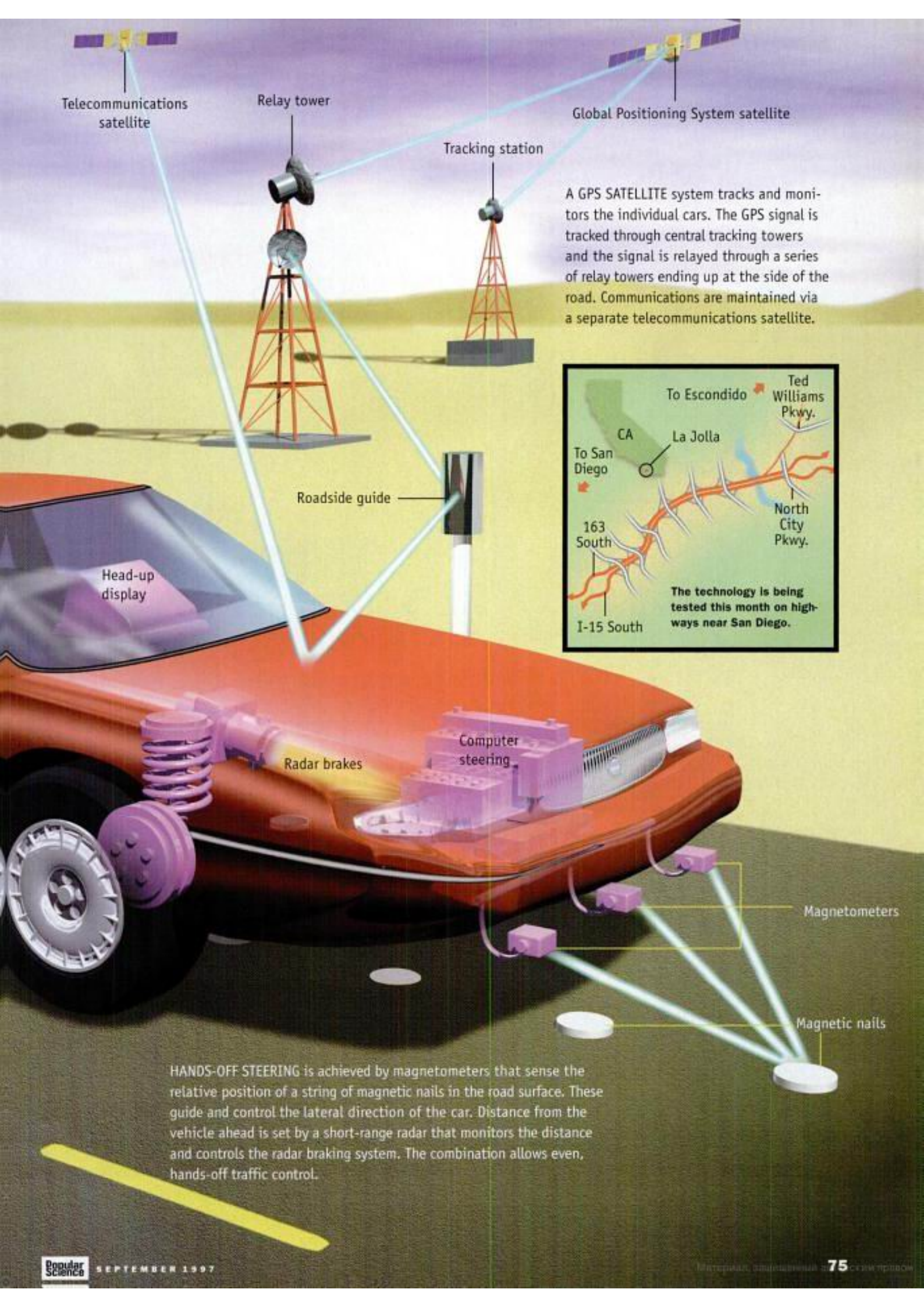
the driverless car, I left cones scattered in my wake.

Yes, the LeSabre steered flawlessly at the test track. But why would we want cars to do their own driving?

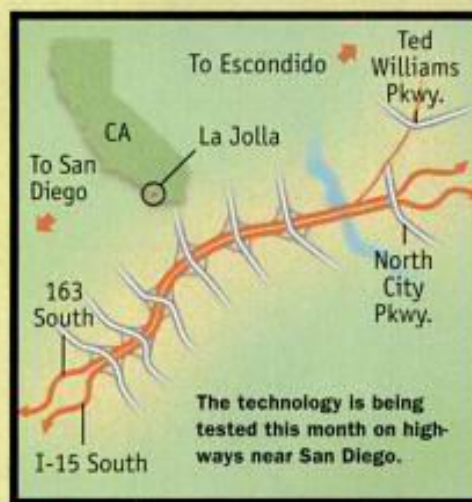
With main arteries gridlocked and the construction of additional roadways in most metropolitan areas an impossible dream, what will keep traffic flowing in the future? One solution is to automate control of cars in special lanes, enabling the vehicles to travel safely at high speeds in tightly packed platoons. Proponents claim this will double or triple vehicle capacity on existing roads, leading to significantly less traffic congestion.

Sure, it isn't the Jetsons... but it's close. ▶

ILLUSTRATIONS BY SLIM FILMS



A GPS SATELLITE system tracks and monitors the individual cars. The GPS signal is tracked through central tracking towers and the signal is relayed through a series of relay towers ending up at the side of the road. Communications are maintained via a separate telecommunications satellite.



HANDS-OFF STEERING is achieved by magnetometers that sense the relative position of a string of magnetic nails in the road surface. These guide and control the lateral direction of the car. Distance from the vehicle ahead is set by a short-range radar that monitors the distance and controls the radar braking system. The combination allows even, hands-off traffic control.

Sabers of Light

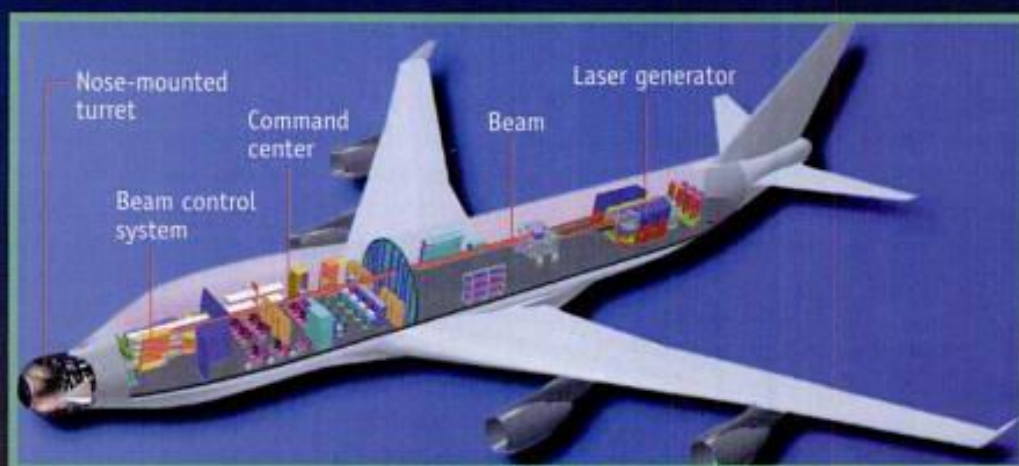
New laser



VERY SOON NOW, in the early moments of dawn, the sun will briefly illuminate a dying satellite. Deep in the New Mexican desert, a group of U.S. Army technicians will witness the moment and grasp it as an opportunity. The sun lights up the target. As if on cue, a high-energy laser beam streaks upward, traveling in the blink of an eye beyond the sky and into space, locking onto the orbiting satellite. Within seconds, the satellite seems to expand, and then disintegrates.

The U.S. Army won't say exactly when this scenario will unfold, but a window of opportunity will open in the next few months as an unspecified satellite reaches the end of its useful existence. When the test occurs—and

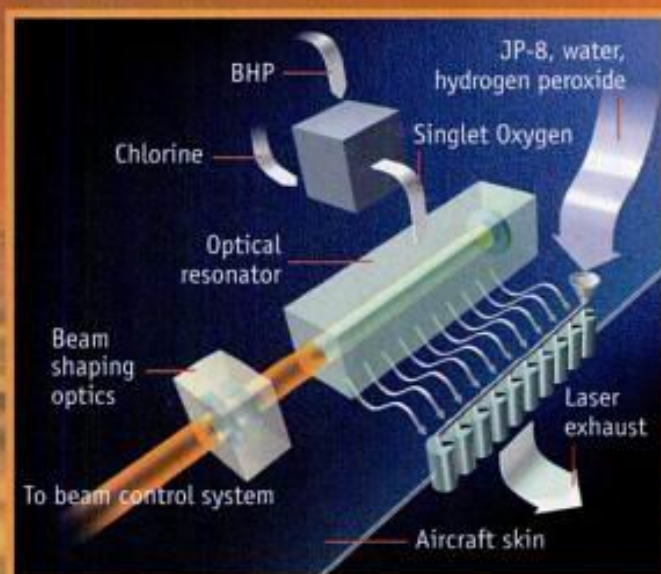
few doubt it will be successful—at the High Energy Laser Systems Test Facility (HELSTF) on the White Sands Missile Range in southern New Mexico, it may mark a turning point in warfare. For the first time, the military will be able to do more than respond to a bullet with merely another bullet. Big bullets—missiles—will be answered by lasers. And the lasers won't emanate only from ground-based installations like the White Sands facility. In the coming years, planes equipped with lasers will intercept short-range missiles just after they are launched. Likewise, a squadron of space fighters armed with lasers will destroy long-range missiles before they get anywhere near their destinations, eliminating as well the orbiting satellites



The laser beam travels the length of the space plane before it shoots out the turret.

Weapons breathe life into an old Star Wars plan for missile defense.

By Mark Farmer and Frank Vizard



How the Airborne Laser Works

CREATION OF THE laser beam aboard the airborne laser aircraft begins with the Chemical Oxygen Iodine Laser (COIL) device housed in the plane's cargo area. Hydrogen peroxide is mixed with chlorine gas to produce an excited form of oxygen called singlet delta oxygen (SDO). Iodine is injected into the SDO to create an excited version labeled I^* . As the I^* relaxes to its base energy state, a photon with a wavelength of 1.3 microns is produced, the optimum wavelength for transmission through the atmosphere. The photons are harvested from the lasing cavity by an optical resonator, which strips the I^* of its energy as it bounces back and forth. From the resonator, the photons are funneled through the beam-shaping optics to the beam-control system and then out across the sky to the target.

that convey targeting information to the enemy.

Missiles, in fact, are the catalyst behind the development of the laser as a weapon. Potential adversaries around the world are increasing their long- and short-range missile stockpiles, and most experts think that in a future conflict, the enemy will also possess cruise missiles similar to those that have worked so well for the U.S. military.

Until now, missile defense rested on the concept of hitting a bullet with another bullet. But that's easier said than done. The Patriot missile defense system used in the Gulf War was not as effective as reports at the time indicated—only a few incoming Scud missiles were actually destroyed. Unless hit at a very specific angle and location, the enemy missiles broke into pieces, with no guarantee that the payload had been destroyed or that the pieces themselves were not deadly, particularly if the weapon was biological or chemical.

With longer-range missiles, the problems are similar. A single missile can carry hundreds of submunitions—some as tiny as a football—that are difficult to track and destroy once they are released. Small, smart weapons that would act like bullets to destroy these submunitions are being researched, but numerous obstacles must be overcome. To date, tests of these weapons have been unsuccessful, and at best they may be effective only against a "rogue" missile fired by terrorists or by accident. They are also costly to build and deploy. The problems are compounded by the fact that current treaties prohibit the development of national missile-defense systems.

In such an environment, the flexibility of laser weapons makes sense. This opinion has been given voice for a decade—its roots can be traced to President Reagan's Strategic Defense Initiative, or "Star Wars," program. While only the movie of the same name has remained on the public's radar screen, the military in the meantime, with the U.S. Air Force taking the lead, has quietly been developing its own long-range version of Luke Skywalker's light saber.

Planes with Lasers

At a distance, the unknowing could dismiss the airplane as just another jumbo jet, perhaps one with a few extra bumps and a curious-looking snout. But that blunt proboscis is the sharp end of the YAL-1 Airborne Laser (ABL), the Air Force's most novel aircraft, truly a weapon of mass protection. Flown by a crew of two and operated by a team of four, the Airborne Laser is designed to operate autonomously—intercepting tactical ballistic missiles in their vulnerable boost phase, shooting down cruise and surface-to-air missiles, protecting reconnaissance aircraft from air-to-air missiles and peering deep into enemy territory with extremely precise optics.

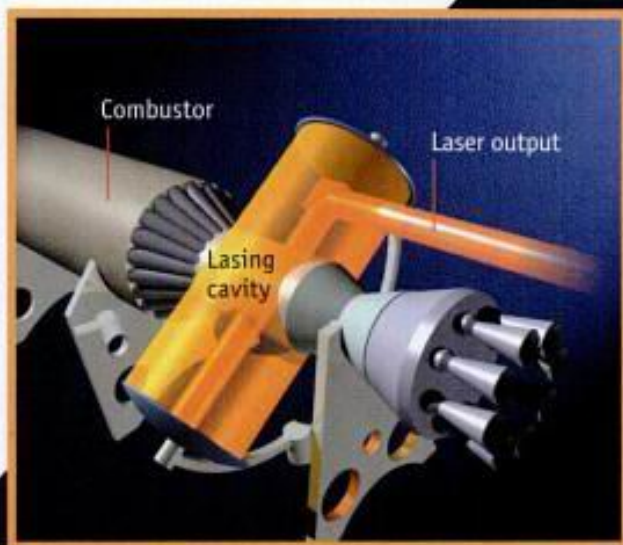
Boeing is the prime contractor, integrating the multi-megawatt TRW Chemical Oxygen Iodine Laser (COIL) and the Lockheed Martin beam director and Infra-Red

Search and Track (IRST) systems onboard a converted 747-400F freighter. A full-power, flight-weight test is set for April of next year, and the big money shot is scheduled for 2002, when the ABL prototype is to shoot down a tactical ballistic missile.

The technology to build the ABL is within reach at a remarkable cost of less than \$6 billion for a seven-aircraft squadron slated to be fully operational by 2008. "The ABL will be revolutionary because of its ability to detect, target, and instantaneously destroy enemy targets at hundreds of kilometers," says Air Force Secretary Sheila Widnall. "This will be the first time a nation has developed a militarily effective high-energy laser weapon. We believe the individual technologies are proven, but we must now integrate these technologies onto an airplane with weight and operational restrictions."

As presently envisioned, one ABL at a time will fly above the cloud deck at altitudes exceeding 40,000 feet—tracing figure-eight circuits, 90 kilometers or so, behind the front lines and extending its time in the air by using aerial refueling. Targets are sighted by the infrared system, made up of modified F-14D Tomcat sensors, which provide a 360° field of view. Targets are relayed to a illuminating beacon that floods the plane's nose cone with laser energy. The targeting illuminator laser then locks onto and begins to track the missile. At the command to fire, the high-energy laser punches a hole in the target. A nominal magazine load for the ABL will provide at least 20 shots. Costs are estimated at a relatively low \$25,000 per mission. "It's a





The deuterium fluoride chemical laser at the White Sands test facility works like a rocket engine. Ethylene fuel is burned with an oxidizer, nitrogen trifluoride, yielding excited fluoride atoms. Just downstream from the combustor, deuterium and helium are injected into the exhaust. Deuterium combines with the fluoride while helium stabilizes the reaction. The resonator mirrors extract optical energy that becomes a laser beam approximately 21 centimeters high and 3 centimeters wide. Output power can be varied by altering the fuel rate and mixture.

Shooting Satellites from the Sky

CONSIDERED TO BE the most powerful laser in the United States, the MIRACL device at the White Sands testing facility is capable of destroying satellites in orbit, disrupting enemy communications and surveillance activities. MIRACL has already destroyed a number of drone aircraft and a missile in tests. The beam director, mounted on a 5.1-inch gun turret, can swing across the sky in a 350° arc, holding the laser on target for as long as it takes to disintegrate the target—generally, a matter of seconds.

lot of bang for the buck," says Col. Mike W. Booen, USAF airborne laser-systems director.

Chemical waste is passed via a catalytic converter and piped through ejectors, leaving the plane as exhaust. This waste is benign, says John Waypa, TRW airborne laser-program manager. "Over 90 percent of the elements present in the exhaust occur naturally in the atmosphere."

Satellite Hunter

While technicians in White Sands wait for permission to obliterate an orbiting space satellite, they are already confident of their ability to track and destroy a fast-moving object. The Mid Infrared Advanced Chemical Laser (MIRACL), a complex array of telescope and mirrors married to computerized tracking and stabilization systems, is the most powerful laser in the United States. But the key component at White Sands is the Hughes-made Sealite beam director, which locks the MIRACL laser beam onto its target. Mounted on a 5.1-inch naval gun turret with a fast 350° swivel motion, the 28,000-pound beam director is surprisingly nimble. It includes both a small targeting laser and a 1.5-meter high-power

aperture. The minimum range of the MIRACL laser is 400 meters; the maximum range is still unknown.

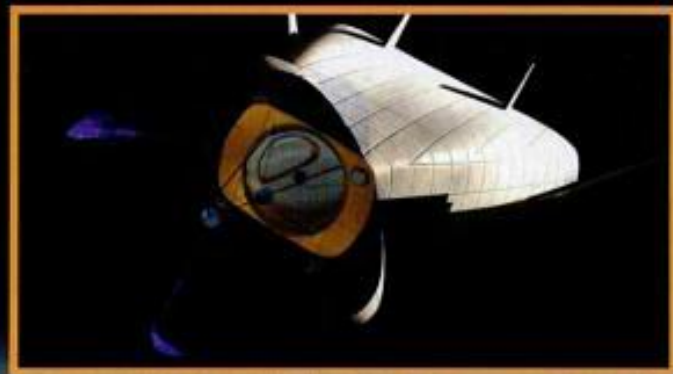
This laser has already demonstrated its effectiveness as a weapon. On Feb. 9, 1996, a short-range rocket was destroyed in flight over White Sands. This test was part of a joint effort with Israel to develop a tactical high-energy laser (THEL). Such a weapon would be able to fire repeated bursts at the speed of light in situations in which a defense against short-range missiles must be mounted quickly. THEL is considered a tactical weapon because it is designed to protect a specified local area; such a system could supplant the Patriot missile-defense system. Like the MIRACL system, THEL uses a deuterium fluoride chemical laser. Tests on a portable THEL should begin next year. In the meantime, the beam director points toward space, tracking satellites as a prelude to an attack that would cripple an enemy's communication and surveillance capabilities in time of conflict.

Space Fighters

"When it absolutely, positively has to get there in 60 minutes." That's not the slogan of a new parcel delivery ser-

Laser Weapons in Space

THE U.S. Air Force expects to deploy a squadron of space planes armed with laser weapons within the next few years. These fighters may be manned or unmanned and will be capable of flying a variety of missions, including launching satellites, destroying short- as well as long-range enemy missiles, and performing surveillance missions.



Once envisioned for deployment on satellites, lasers aboard space planes, shown here in an artist's concept, are more politically feasible.



ICBM missiles like the one pictured could be destroyed immediately after launch.



vice. Rather, it is an expression of the strategy that is driving the U.S. Air Force into space. The Air Force envisions craft that return from space and relaunch in less than an hour. Military planners salivate at the thought of a squadron of these planes for reconnaissance, attack, destroying enemy satellites, and launching space missions.

"In any conflict, you want the high ground and space is the ultimate high ground," says Gen. David Vasily, assistant chief of staff for the USAF.

"Space-plane development had never been given a sustained push, because it looked like an expensive proposition without any probable combat impact," says Merrill A. McPeak, a retired USAF general and former Air Force chief of staff and now chairman of the board at Pioneer Rocketplane, a Denver-based company seeking to produce an economically viable space plane.

"The situation has changed," McPeak says.

"Due in part

to the new emphasis on infowar, we now understand how important the constellation of space assets is." They have the potential to win a war and could certainly lose one if they were compromised, he adds.

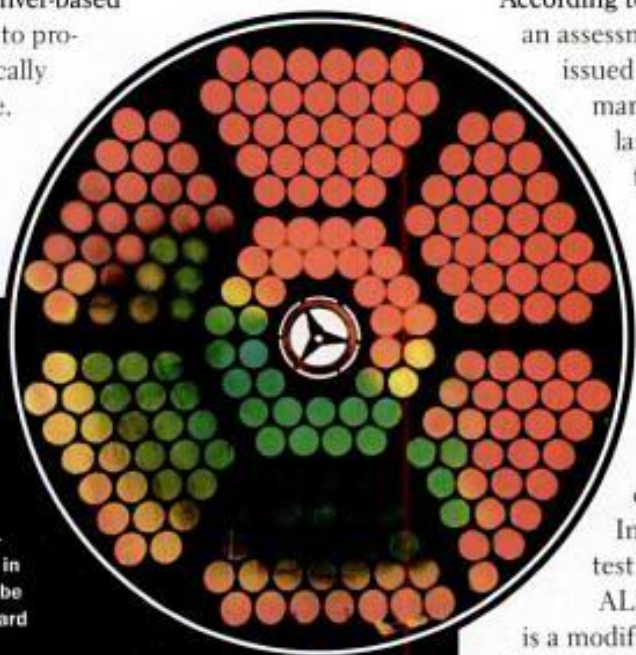
Air Force Secretary Widnall seems to agree. "We must be able to access space-based systems—and space—as rapidly as we can now project a bomber to distant trouble spots." It seems unlikely, however, that the world would tolerate a permanent space-based laser weapons platform operated by the United States or any other country. In fact, the Anti-Ballistic Missile Treaty of 1972 prohibits the deployment of space-based lasers. Having the same capability for a short time in a crisis situation via space planes would probably be more acceptable politically. According to the USAF's own New World Vistas report, an assessment of 21st century defense requirements issued this year, future military space planes, manned or unmanned, will be equipped with lasers and be in operational squadron use by the year 2030. In all likelihood, their arrival will come far sooner.

The space laser itself may follow the lines of a TRW project that seeks to integrate the company's Alpha high-energy hydrogen fluoride chemical laser, which performs more reliably in space than other lasers, with a Hughes 4-meter beam projection telescope and a Lockheed Martin beam control system. This small Alpha LAMP Integration (ALI) system underwent its first test firing in March.

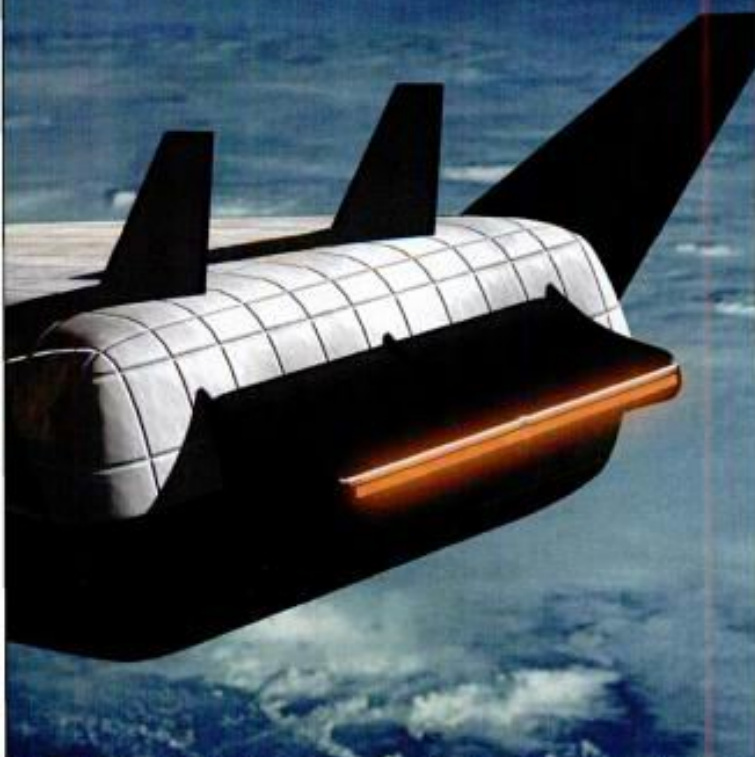
ALI will likely be put aboard a space fighter that is a modification of an existing space plane design. NASA and the Lockheed Martin Skunk Works are pursuing the X-33 and VentureStar (X-34) reusable launch vehicles designs, scheduled to fly by 2004 ["VentureStar: 21st Century Space Shuttle, Oct. '96]. The USAF has opened an office at the Phillips Laboratory research center at Kirtland Air Force Base in New Mexico to study the idea. "An orbital vehicle would be relatively smaller than the physical size of a B-1 bomber. We are looking for aircraft-like operations, and our main concerns are durability and reliability," says Lt. Col. Jess M. Sponable, military space-plane program manager at Phillips.

The VentureStar is on the fast track for development. NASA has already created an engine, appropriately called Fastrac, which will power the X-34 technology demonstration vehicle on its first flight in late 1998. The cost of the engine was about \$1 million (about one-seventh the cost of similar engines). The Fastrac engine is about half the size and one-third the weight of a space shuttle main engine.

Once deployed, the space plane, as well as the ABL aircraft and ground systems like THEL, will change the military landscape dramatically. Controlling space, air, and land won't depend on how big or fast your bullets are but how powerful a laser you have in your arsenal. ♦



TRW's Alpha hydrogen fluoride laser is designed to work in space and can be sized to fit aboard a space plane.



Reports on the death of the personal digital assistant were apparently premature

By Suzanne
Kantra
Kirschner

Return of

WHEN APPLE INTRODUCED the Newton in 1992, a new product category was born: the personal digital assistant, or PDA. The promise—and the hype—seemed boundless: a computer that could organize your life, read your handwriting, and fit in your pocket. Trouble was, the early PDAs were a crude, cranky lot that didn't deliver all they promised. The Newton's unpredictable handwriting recognition quickly became more popular as a party game than as a useful tool. The early PDAs were also too big for most pockets and didn't communicate easily with the outside world. Not surprisingly, PDAs bombed.

But even with this miserable beginning, the notion of a digital helper was too good an idea to be squashed. And indeed, U.S. Robotics resurrected the PDA in 1996 with its Pilot: A sleek device only slightly larger than a deck of cards, the Pilot was small enough to slip into a suit jacket pocket without making an ugly fashion statement. More important was that, rather than attempting to fly solo, the Pilot was designed to be, well, a co-pilot of sorts, serving as an untethered adjunct to your primary computer. Your appointments, contacts, notes, to-do lists, and expenses could all be synchronized with your desktop PC by seating the Pilot in its cradle and pushing a single button. It even had a form of handwriting recognition, called Graffiti, that was fairly reliable.

Since then, a slew of PDAs have followed, including a new version of the Pilot called the Palm Pilot Pro. The Pilot now has an emulator, too, in Sharp's new SE-500. There's yet another new edition of the Newton, called the MessagePad 2000, and a new model 5 from veteran PDA manufacturer Psion.

Then there was the big shoe that dropped. Microsoft

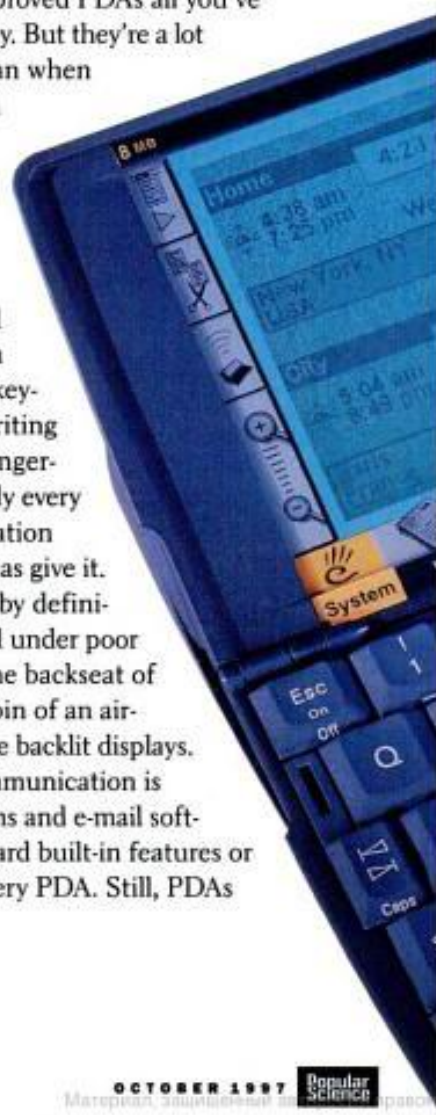
finally got around to releasing a version of its Windows operating system specifically for pocket PCs, dubbed Windows CE, and that unleashed a small torrent of entries from the likes of Casio, Compaq, Hewlett-Packard, Hitachi, NEC, and Philips. (Of this group, we evaluated the Philips Velo 1 for this report.)

Are these new-and-improved PDAs all you've been wishing for? Not likely. But they're a lot closer to the bull's-eye than when the first Newton fell from the Apple tree, and some fundamental lessons have clearly been learned.

Lesson one: The human hand is not designed to enter lots of data into a small machine. The tiny keyboards and spotty handwriting recognition are just too finger-numbing for that. So nearly every PDA now can get information from desktop PCs, as well as give it.

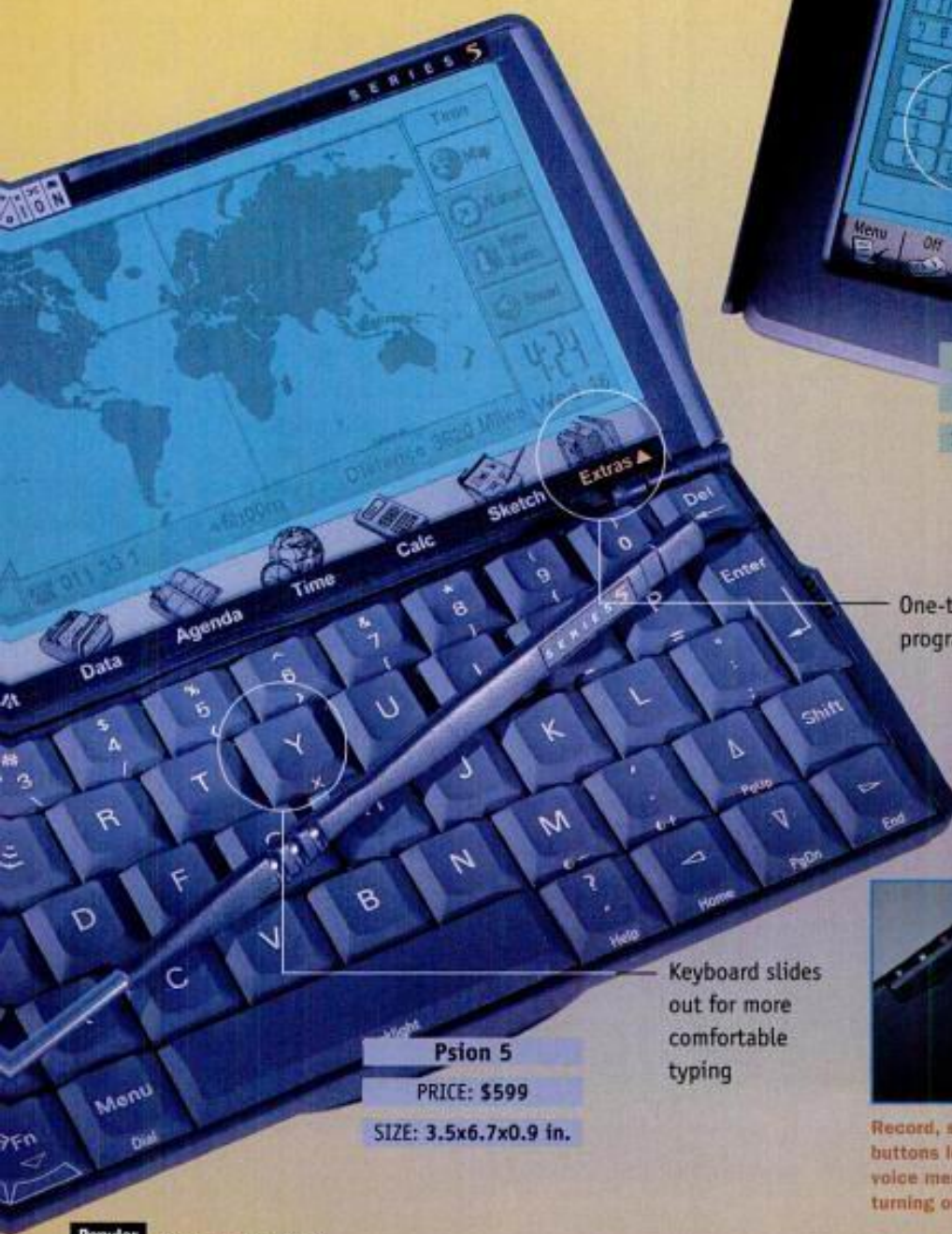
Lesson two: PDAs are by definition portable and are used under poor lighting conditions, like the backseat of a taxi or the darkened cabin of an airplane. The new PDAs have backlit displays.

And lesson three: Communication is absolutely critical. Modems and e-mail software are now either standard built-in features or available as options on every PDA. Still, PDAs



PHOTOGRAPHED BY JOHN B. CARNETT

PDA's the PDAs

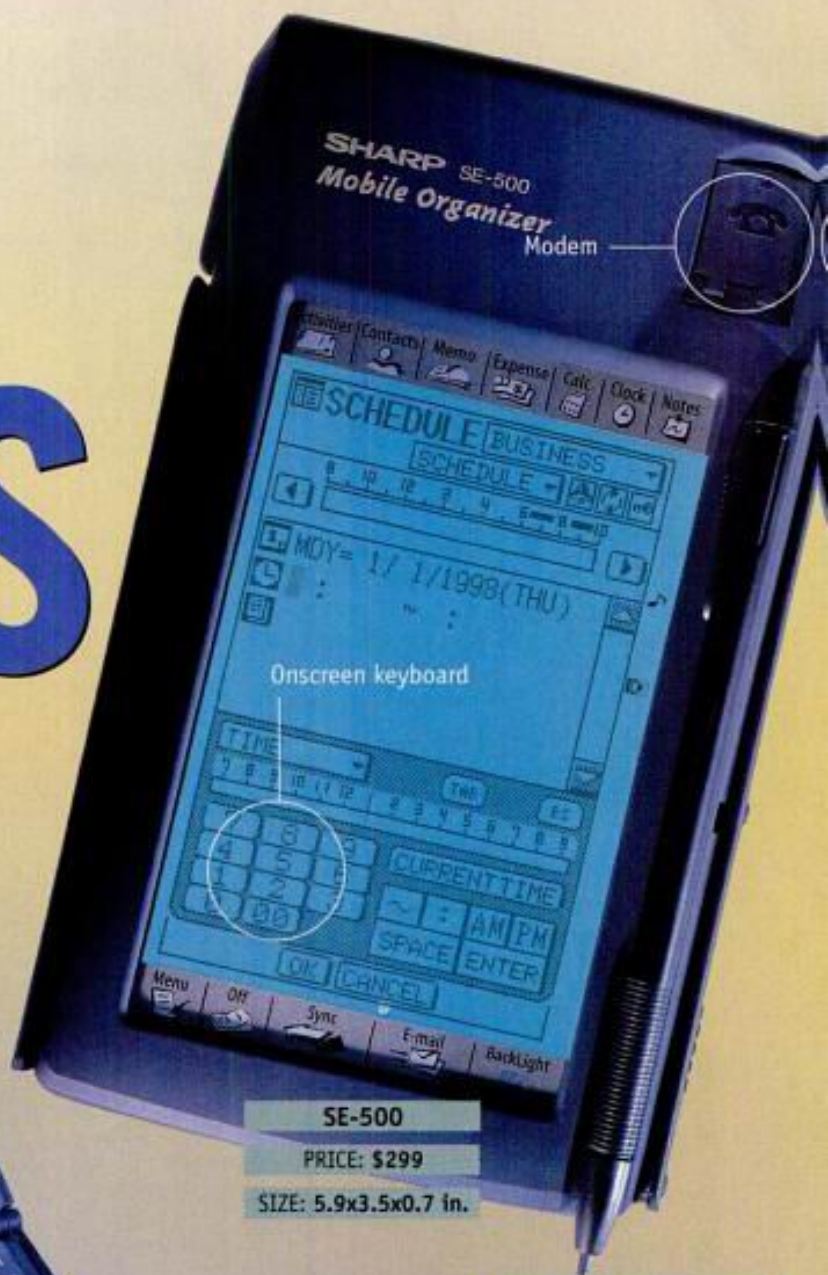


Psion 5

PRICE: \$599

SIZE: 3.5x6.7x0.9 in.

Keyboard slides out for more comfortable typing



SE-500

PRICE: \$299

SIZE: 5.9x3.5x0.7 in.

Onscreen keyboard

One-touch program access



You can send and receive e-mail via the SE-500's built-in 14.4Kbps modem.



Record, stop, and play buttons let you record voice memos without turning on the Psion 5.



NAME	PSION 5	MESSAGEPAD 2000	PALM PILOT PRO	SE-500	VELO 1
MANUFACTURER	Psion	Newton Inc.	U.S. Robotics	Sharp	Philips
PRICE	\$599-\$699	\$949-\$1,099	\$399	\$299	\$699-\$739
MODEM	Optional: PC Card adapter (\$139) plus modem, or 14.4Kbps travel modem (\$249)	Optional: PC Card modem	Optional: proprietary modem (\$129)	Yes, 14.4Kbps	Yes, 19.2Kbps
PC CONNECTION	Serial cable; infrared; includes links to 2 popular organizer programs	Serial cable; infrared; includes links to 2 popular organizer programs	Desktop cradle; additional purchase for link to popular organizer programs (\$69)	Desktop cradle; includes links to 3 popular organizer programs	Desktop cradle; includes links to Microsoft Schedule 7.0a
SIZE (INCHES)	3.5 by 6.7 by 0.9	8.3 by 4.7 by 1.1	4.7 by 3.2 by 0.7	5.9 by 3.5 by 0.7	3.8 by 6.8 by 1.0
WEIGHT (OUNCES)	12.5	20	5.7	6.5	14.8
SCREEN RESOLUTION	640 by 240 pixels	640 by 320 pixels	160 by 160 pixels	240 by 159 pixels	640 by 240 pixels
INPUT TYPE	Integrated keyboard	External keyboard, handwriting recognition	Onscreen keyboard, Graffiti handwriting recognition	Onscreen keyboard	Integrated keyboard
EXTRA FEATURES	External voice memo activation	Internet browser preinstalled	Large selection of 3rd party software available	Zero-touch synchronization when in cradle	External voice memo activation, Internet browser preinstalled
OPERATING SYSTEM	EPOC32	Newton 2.1 OS	Palm OS	Sharp OS	Windows CE

are far from cookie-cutter devices—or experiences.

If you're on the road often with a PDA as your portable computer, then size may matter less than a PDA's ability to collect and communicate information. The Newton

MessagePad 2000, with its external keyboard and 640- by 320-pixel display, is by far the best choice if you're going to type long memos and e-mail, or work on spreadsheets. And its pair of PC Card slots enable you to use the latest

modem technology while leaving room for extra storage. But you'll have to weigh that against the fact that this is a heavy and, with the separate keyboard, clumsy PDA. And chances are, you don't want to leave the keyboard. The Newton's handwriting recognition is vastly improved, but if you got less than a B+ in penmanship, it probably won't work well enough.

In the more likely event that you're reviewing documents and responding to e-mail rather than creating lots of original material, the compromise embodied by the Velo 1 and Psion 5 may make for easier traveling. They



Browse the Internet with the Velo 1's built-in 19.2Kbps modem.

Velo 1

PRICE: \$699

SIZE: 3.8x6.8x1.0 in.



Pilot Pro

PRICE: \$399

SIZE: 4.7x3.2x0.7 in.

Graffiti handwriting
recognition input area



The Pilot Pro's docking station provides one-button synchronization with a desktop computer.

are substantially smaller and lighter than the MessagePad and have built-in, if very small,

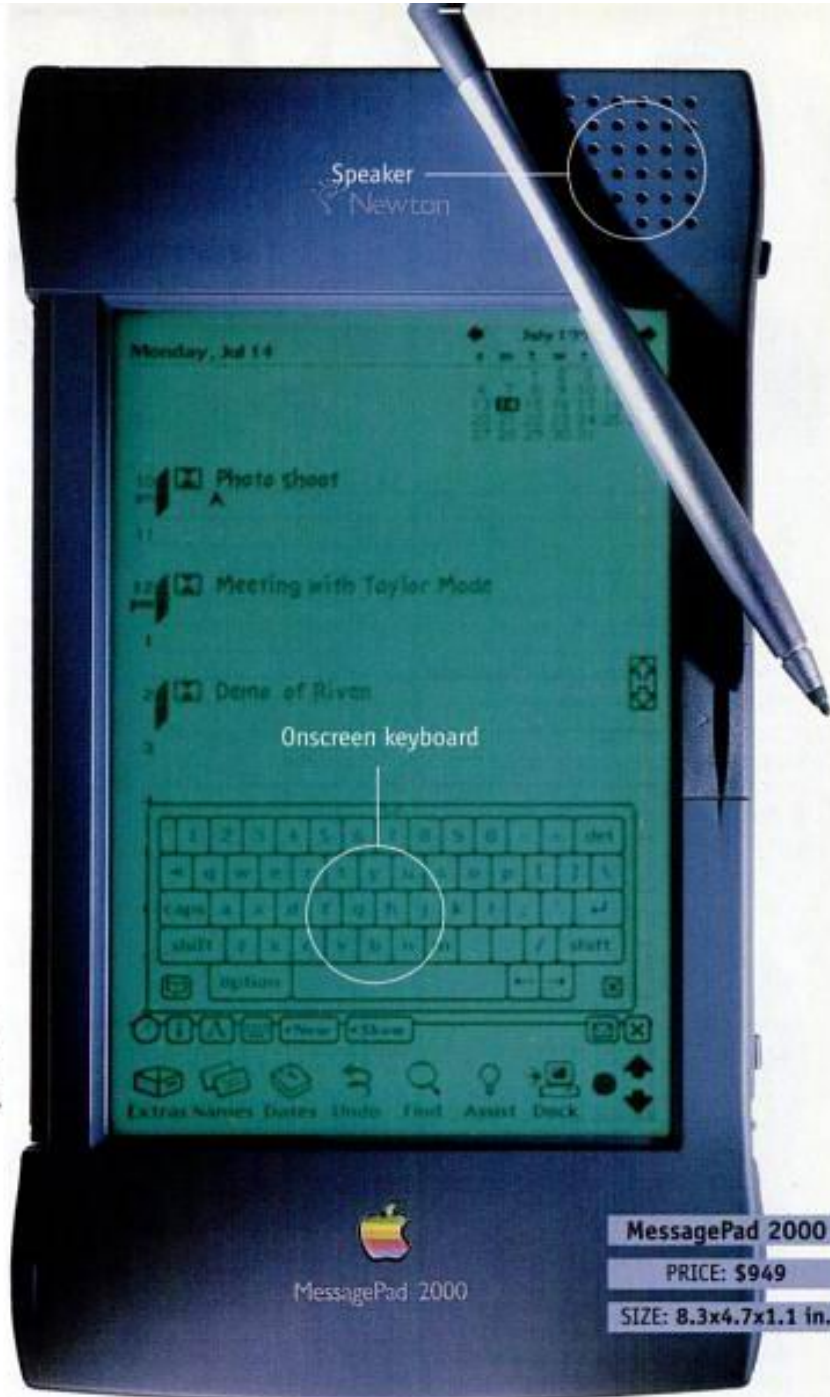
keyboards. The Velo has a built-in modem and takes miniature flash memory cards for extra storage; the Psion has a PC Card slot for a modem or extra file space. They have reasonably equipped spreadsheet and word processing programs, and the Velo comes with an Internet browser.

You'll find typing to be a pleasant experience on neither. The Velo has a standard layout but tiny button-style keys. The Psion's keys are much larger, but keyboard layout is not the traditional qwerty style.

If you're merely looking for a way to keep track of all those brilliant ideas that only seem to pop into mind outside the office, you may not need the keyboard at all. The Psion and Velo each have a voice memo function that you can use even when they are closed up.

If you don't mind jotting things down, you can choose an even lighter traveling companion. The smaller Palm Pilot Pro uses the Graffiti handwriting recognition system rather than a keyboard. You'll have to learn the Graffiti alphabet, numbers, and punctuation, but it's a familiar, intuitive, and forgiving system. The Pilot Pro can track expenses and help you create, read, and reply to e-mail. But all e-mail is sent and received via your desktop PC unless you install additional software and buy the travel modem.

If you don't plan on inputting much of anything, but want to stay in touch, Sharp's SE-500 may be your ticket to ride. It comes with software to send and receive Inter-



Speaker
Newton

Onscreen keyboard



MessagePad 2000

MessagePad 2000

PRICE: \$949

SIZE: 8.3x4.7x1.1 in.



The MessagePad 2000's handwriting recognition software can read cursive and printed characters.

net e-mail via its built-in, if a bit pokey, 14.4Kbps modem. But entering data or responding briefly to e-mail messages can be a chore with its minuscule onscreen keyboard; canned e-mail responses are available.

Not sold yet? PDAs with color screens from Sharp, Casio, and others are coming later this year and next. More Pilot clones seem inevitable, too, with Microsoft reportedly working on a new PDA operating system more attuned to the Pilot's strengths. The long-awaited marriage of phones and computers may finally be consummated with new PCS voice-and-data services, too.

Who knows? With so many PDAs coming, you may yet find a pocket computer that's just your size. ♦

AUTOMOTIVE

EDITED BY DAN McCOSH

SPEED RECORDS

Boom! Mach 1

WITH A SHOCK wave cutting a line across Nevada's Black Rock desert floor like the bow wave of a ship, Richard Noble's ThrustSSC established a new land speed record of 763 mph on a two-way timed run this past October, pushing the official record to a speed above Mach 1, the speed of sound. Mach 1 varies according to weather and altitude; during the record run, it was calculated at 748 mph.

The run probed unexplored dimensions of aerodynamics. At Mach 1, aircraft project a cone-shaped shock wave from the leading edges. What would that shock wave do under a vehicle rolling on wheels? As it turned out, the stability of the ThrustSSC demonstrated that a carefully shaped car body could, in

fact, run faster than Mach 1 without being lifted by the wave's impact.

The ThrustSSC, driven by jet pilot Andy Green, was developed by a British team lead by Noble, breaking his own land speed record of 633 mph, set in 1983. Green set a short-lived record of 714 mph a few weeks before the 1997 record run.

Early calculations by aerodynamicist Ron Ayers, a member of Noble's team, indicated that the instability posed by the reflected shock wave was not insurmountable. But no wind tunnel could create the appropriate conditions. Instead, Ayers' early calculations were supported by work with rocket-powered models and then tested on a track that was originally developed to test the high-speed stability of missile nose cones.

The ThrustSSC is essentially a jet airplane without wings. Its two Rolls-Royce jet engines produce 50,000 pounds of thrust—equivalent

to 110,000 horsepower. Development of the ThrustSSC took two years, with a 1996 run in Jordan thwarted both by mechanical troubles and torrential rains.

The Noble team's achievement came as it alternated runs at the record with American Craig Breedlove in his Spirit of America jet car. Breedlove had attempted a record in October of 1996, an effort that ended in a spectacular crash.

Green is the first to achieve a certified land speed record faster than sound—which requires two runs over a measured course, with the return run attempted less than an hour later to make it official. The certification distinguishes the ThrustSSC from such craft as the Budweiser Rocket, which is claimed to have broken the sound barrier in 1979 for an instant while making an unofficial run [Letters, June].

Technically, the sound barrier also was broken on land in the early 1950s by several rocket-powered sleds running on rails ["Lethal Force," May].—D.M.



ThrustSSC pilot Andy Green gets a salute from Richard Noble after the sound barrier fell.

The two Rolls-Royce jet engines are mounted on pylons alongside the ThrustSSC's body—a position calculated to keep them out of the path of the shock wave at Mach 1.

The wheels are solid aluminum discs.

The ThrustSSC is steered by the rear wheels, because the front wheels are situated where room to move is limited.

A high plume forms from the dusty surface of the desert during a high-speed test run.

An active suspension system keeps the body at the angle necessary for constant aerodynamic downforce.

ILLUSTRATION & BOTTOM RIGHT PHOTO COURTESY OF CASTROL; RETROSPECTIVE CASSETTE/ARCHIVE PHOTOS

larly at high speeds. The S-92 is designed to cruise comfortably at 180 mph, which is a speed at which most helicopters start to shake and vibrate. The transmission and rotor mast are attached to the fuselage by flexible links and hydraulic actuators. Sensors on the transmission detect vibration, and a computer issues commands to the actuators, which generate countering motions at the same frequency.

The first S-92 should fly this year. Conservatism again: Despite pressure from customers, Sikorsky does not want to take any orders until it is sure how the new helicopter performs. "We have people chasing us for orders," says company president Gene Buckley. The company could start production within a few months, leading to deliveries in 2001. Not all of

Sikorsky's plans are conservative. Sikorsky engineers have designed what could be the generation-after-next in rotorcraft: a tilt-rotor with telescoping blades. Like Bell's tilt-rotors, it would have a quiet, efficient, large-diameter rotor for hovering, but the propellers would shrink in level flight, permitting cruise speeds well above 400 mph.

The dreams of the late-1940s futur-

ists, who saw the helicopter replacing the airplane, may never be realized. However, the 2000s may see the helicopter reach its full potential, as the most versatile means of transportation that humans have invented since the domestication of the horse. ▶



The Bell 609, about the same size as a Learjet, can carry up to nine passengers a distance of 860 miles.



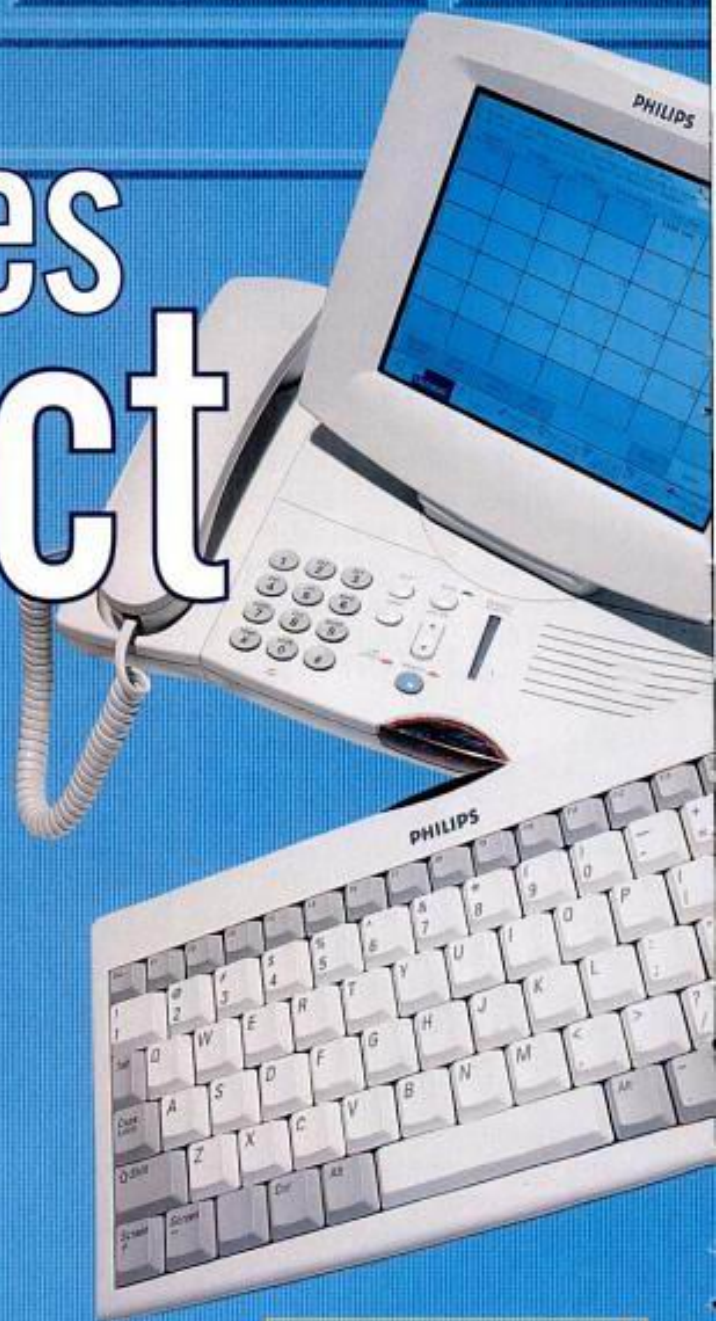
Part Helicopter, Part Airplane

The Bell 609 tilt-rotor flies like a plane, but takes off and lands vertically like a helicopter—making it possible for business travelers to board at a conveniently located helipad or parking lot. That gives the 609 an advantage over business jets, which require a trip to the airport, often through heavy traffic.

Location: |

E-Phones Connect

With new phones, you can check your e-mail and browse the Web without booting up.



By Suzanne Kantra Kirschner

DO YOU SEND AND RECEIVE MORE phone calls or e-mail? When you're looking for information, do you reach for the *World Book Encyclopedia* or the World Wide Web? If your answers are e-mail and the Web, or you wish they were, then a new breed of telecommunications device variously called an e-mail phone or Internet phone may soon find its way into your kitchen or living room.

What's an e-mail phone, or e-phone for short? Essentially, it's the merger of telephone and computer—or at least a tantalizing slice of what a computer provides. With most of these new screen phones, that means being able to

PHILIPS IS-2630

PRICE: \$650

E-MAIL: Any service provider

WEB ACCESS: Yes

SPECIAL FEATURE: VGA color touchscreen

PHOTOGRAPHED BY JOHN B. CARNETT

Stop

read and reply to electronic mail directly from the phone, without booting up (or even owning) a PC. With some, it also means being able to scour the Web to make vacation plans or research homework assignments, albeit at slow speeds and on a rather small screen. And, oh yes, you can still make phone calls, too.

Why an e-phone? This is one invention that seems to be following our lead. Millions of us already exchange e-mail routinely with family and friends at home, not just business colleagues and customers at the office. And the kitchen or the family room is often more conducive to these personal missives than wherever the computer sits, assuming there is one. But if Internet phones serve as e-mail extension cords for the computer savvy, they also promise to get many non-wired relatives back into family circles that went electronic during the 1990s.

Though e-phones are new, you'll have more than a few choices. Alcatel, Cidco, Northern Telecom, Philips, and Uniden are each now selling such phones, or shortly will be, ranging in price from \$300 to \$650. Casio makes a less costly model, the \$149 PhoneMate IT-380, but unlike the others, it receives only the sender's name and message subject line, not the actual message

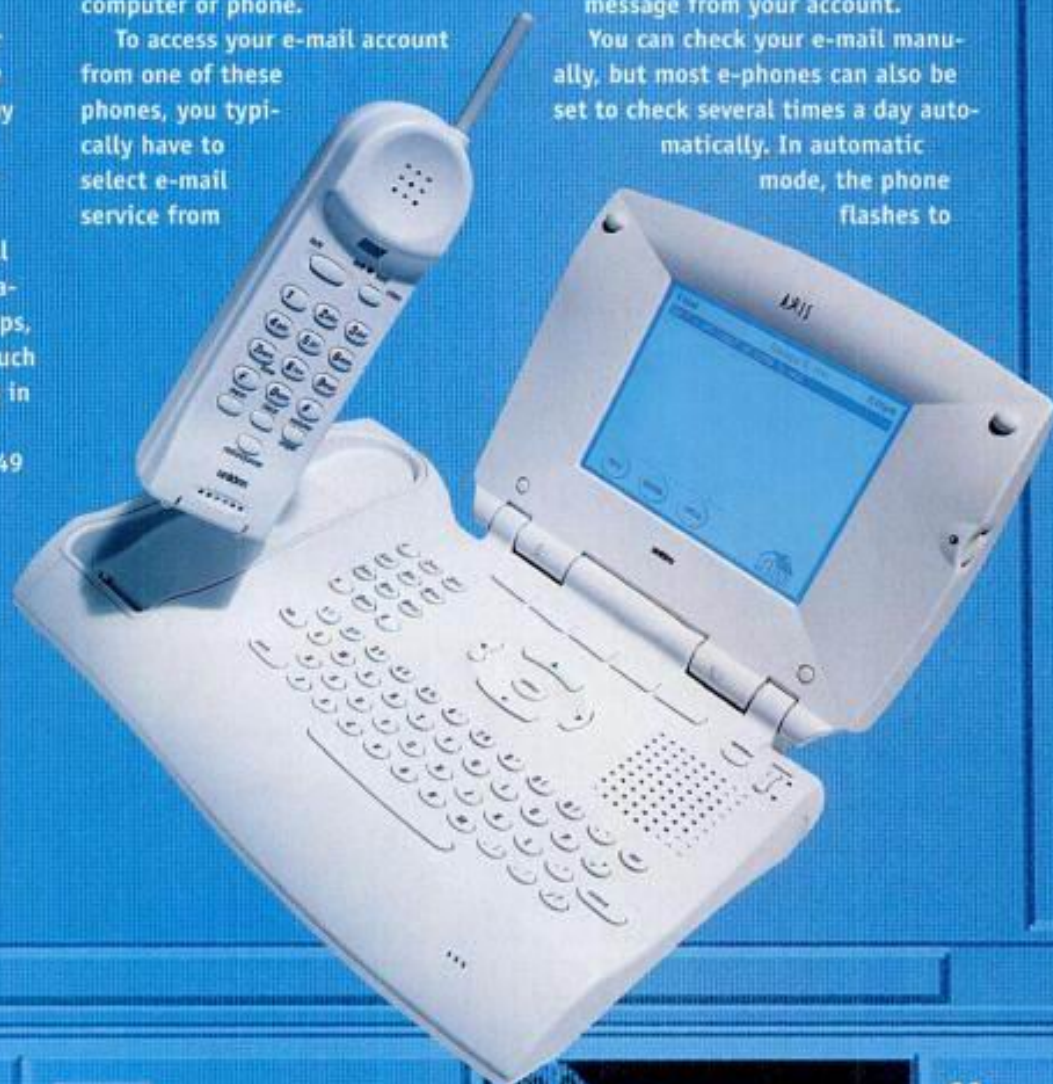
itself—for that you need a PC.

No computer experience is required to use an e-phone. Most let you sign up with your choice of Internet service provider (ISP), which typically charges about \$20 per month. Some phones offer a preselected menu of ISPs, which can make getting started even easier. Ironically, it's harder to set up an Internet phone if you already have an e-mail account. You'll need to get a battery of arcane information from your current ISP, such as server authentication, domain name server (DNS) lookup addresses, and host names. Once you're past this tedious hurdle and enter this account information into the phone, you can check your e-mail from either your computer or phone.

To access your e-mail account from one of these phones, you typically have to select e-mail service from

a menu. Phones with touchscreens have an icon for that on the opening screen. For other phones, you press one of the buttons lining the bottom or sides of the display, much as with an ATM machine. The phone then calls your ISP. When the ISP picks up, the phone automatically transfers your account name and password. Once accepted, the ISP will start sending the phone your messages. They appear in a list with the name of the sender, the subject of the message, and the date the message was sent. By touching the item you want to read or hitting a button next to it, the message will be displayed. Once you've read it, you can reply to the message, move on to the next one, or, with most phones, delete the message from your account.

You can check your e-mail manually, but most e-phones can also be set to check several times a day automatically. In automatic mode, the phone flashes to



UNIDEN EP 200

PRICE: \$450

E-MAIL: Any service provider

WEB ACCESS: No

SPECIAL FEATURE: Cordless phone handset

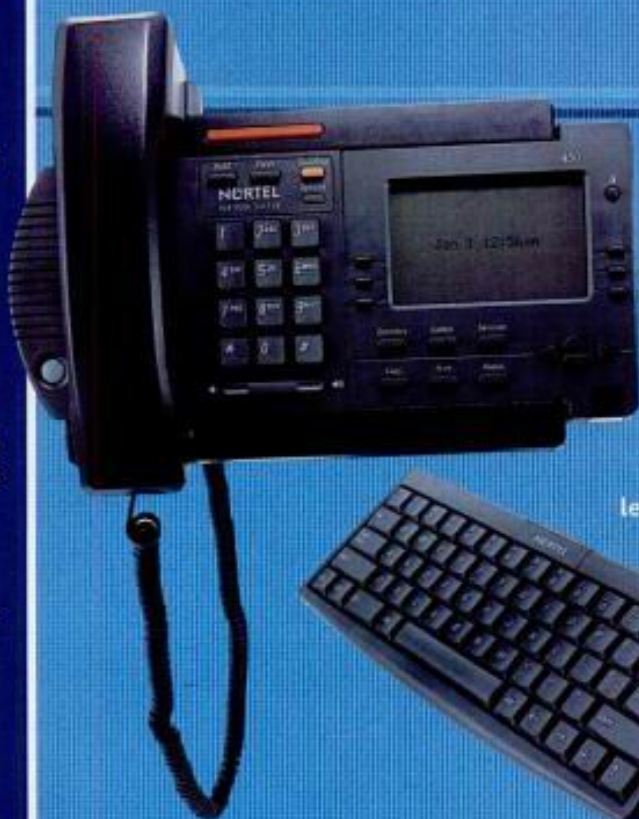
Now Brewing: Java Phones

WHILE TODAY'S Internet phones let you exchange e-mail and maybe do some Web browsing, tomorrow's promise to put an array of products and services at your fingertips, much the way France's Minitel terminals have been doing for years. And the enabling technology will be Sun Microsystems's Personal Java operating system software.

Personal Java can turn a screen phone into a device that can run computer programs, enabling you to order anything from airline tickets to a pizza, either directly or via the Internet. You might call the pizza place as usual, for example, but use a Java "applet" running on the phone's screen to check off your toppings, select a size, and hit the order button. You could even pay for the pizza with a Java smart card, a product that is already being tested.

Not all of a Java phone's added features would necessarily be about purchases. You might be able to subscribe to services that deliver wake-up calls, or remind you about impending anniversaries and birthdays. Other services, such as weather and school reports, might be more local in nature.

Alcatel's model, the 2840 (see main story), is expected to be the first Personal Java phone when it arrives this fall. There are no Java-based services for this phone to take advantage of yet, but some shopping services may be available before the end of this year. Samsung and Northern Telecom say they'll each have Java-based phones ready in early 1999.—S.K.K.



NORTHERN TELECOM POWERTOUCH 450

PRICE: \$299

E-MAIL: SmartServe

WEB ACCESS: No

SPECIAL FEATURE: Optional wireless keyboard (\$70)

less variety are by far the easiest to type on. The slide-out keyboards are considerably smaller and more cramped, and a keyboard drawer adds to the overall size of the phone. But you can't lose the keyboard, and you will never have to replace the keyboard's batteries, as you do with the wireless models.

tell you mail is waiting. If you happen to be using the phone when it is scheduled to check for e-mail, the phone will automatically try again when the line is free.

E-mail by any means can be habit-forming, so it's worth paying close attention to your keyboard options with these phones. The Philips IS-2630 and Northern Telecom Powertouch 450 phones have full-size, wireless keyboards that can be stashed elsewhere when not in use. The others have keyboards built into their units, or tucked away in a slide-out drawer. The wire-

One serious drawback to e-mail by phone is that none of these models can receive (or send) attached files, whether they contain documents or graphics. And since swapping pictures of the kids or grandkids via e-mail appendages has become one of the more appealing aspects of electronic messaging, that's a real loss. Some phones will attempt to display simple text files as part of the message, but other types of files will appear as gibberish, or not at all. If you share the e-mail account with a PC and don't delete the message, however, you can usually retrieve the message and file on your computer.

Screen size matters, too, especially



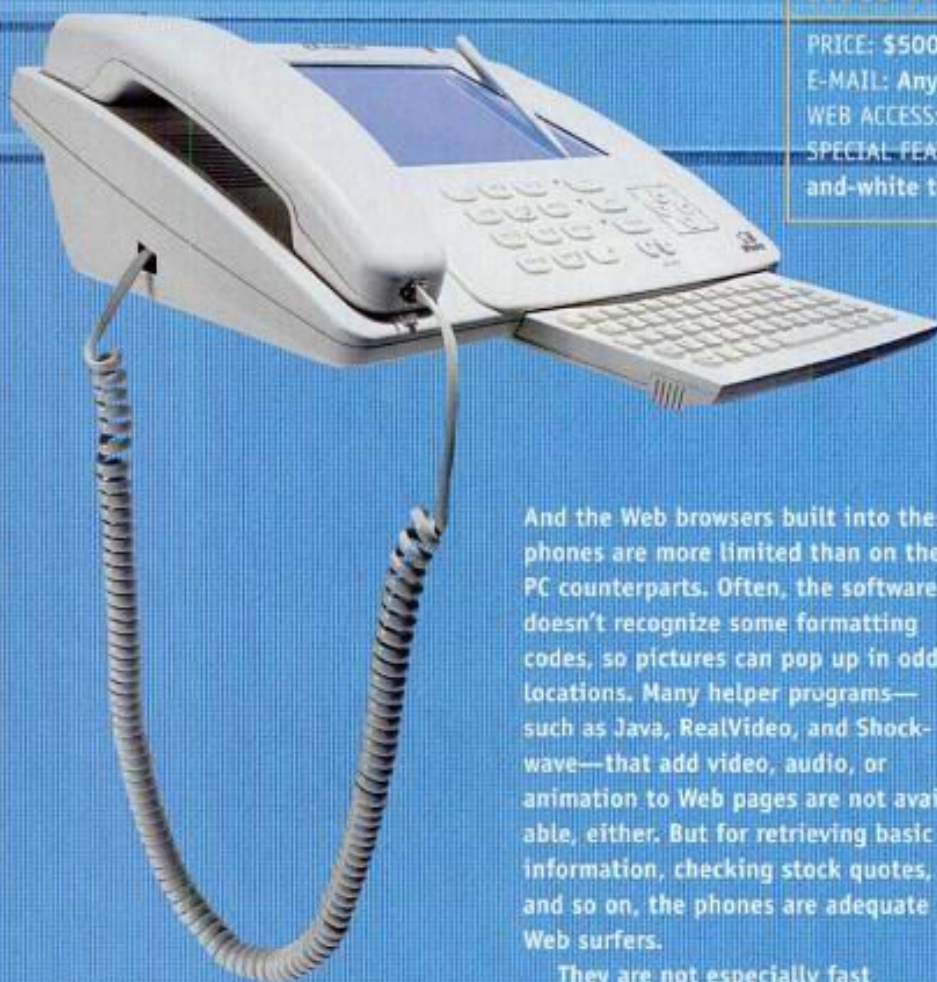
CASIO PHONEMATE IT-380

PRICE: \$149

E-MAIL: Any service provider (sender name and subject only)

WEB ACCESS: No

SPECIAL FEATURE: Answering machine



CIDCO IPHONE

PRICE: \$500

E-MAIL: Any service provider

WEB ACCESS: Yes

SPECIAL FEATURE: VGA black-and-white touchscreen

And the Web browsers built into these phones are more limited than on their PC counterparts. Often, the software doesn't recognize some formatting codes, so pictures can pop up in odd locations. Many helper programs—such as Java, RealVideo, and Shockwave—that add video, audio, or animation to Web pages are not available, either. But for retrieving basic information, checking stock quotes, and so on, the phones are adequate Web surfers.

They are not especially fast surfers, however. The modems integrated into these phones are usually 28.8- or 33.6Kbps models, and you can't trade up later to a higher-speed modem, as you can with PCs. They are up-to-date in most phone features: Most support caller ID, call waiting, and call logging. The Cidco, Philips, and Uniden models have calendars and phone directories as well. Only

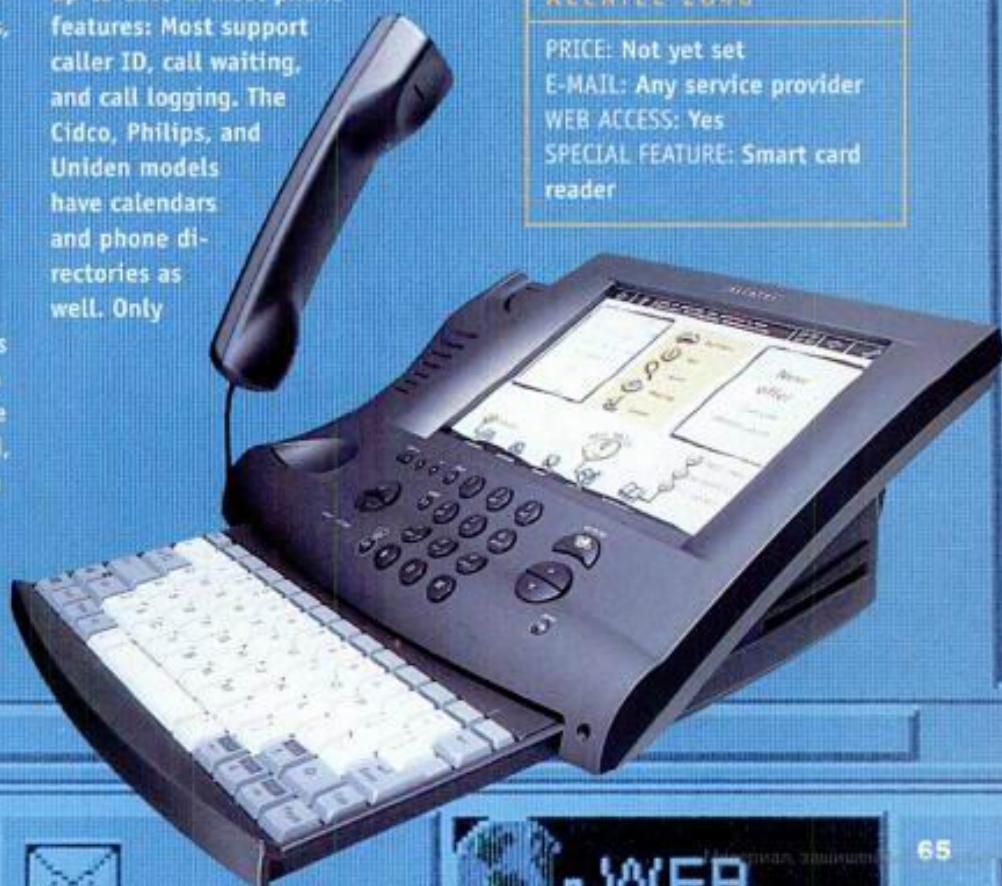
the Casio model has a built-in answering machine, but most support voice mail notification if you subscribe to your local phone company's voice mail service.

More phones are on the way. Early next year, Samsung and others expect to sell Java-based e-phones that will offer even more features and services (see "Now Brewing: Java Phones"). In particular, electronic banking and shopping services are expected to be a part of that expanded menu of options.

Are e-phones really ready for the kitchen? Maybe. Certainly, many of these models cost more than we're used to spending on phones, and they offer something less than the kind of full e-mail and Web browsing capabilities we're used to with computers. But the notion of a universal message center has at least been spawned into the real world, and the kitchen may never quite be the same again. ▶

on e-phones designed to cruise the Web as well as park your e-mail. The Northern Telecom and the Uniden phones, for example, which give you access to e-mail but not the Web, have small, two-tone backlit displays, measuring about 3.5-inches square. By contrast, the Alcatel, Cidco, and Philips phones have displays about twice that size and are touchscreens. Cidco uses a high-resolution (640 by 480 pixels) black-and-white display. The Alcatel and Philips displays are the same resolution, but in color.

Starting a Web browsing session is similar to retrieving your e-mail. You touch a button or screen icon and the phone dials your ISP. Once connected, the default page (often a Web search page like Yahoo or Excite) is displayed. The quality of the graphics is surprisingly good on these phones, but the images are not as big or as sharp as on desktop PCs.



ALCATEL 2840

PRICE: Not yet set

E-MAIL: Any service provider

WEB ACCESS: Yes

SPECIAL FEATURE: Smart card reader

MY HUSBAND THINKS my mystery and romance novels are like dust bunnies. If he spies one lurking under a coffee table or in a dimly lit corner, he knows he's bound to find several more. Ours is a battle of the books. On many occasions, he's threatened to throw away my precious collection. My response is to stash new acquisitions in out-of-the-way spots

so it appears that there are no additions to our overflowing bookshelves.

But now I have a solution to our ongoing conflict. Ironically, it involves yet another book. But this is no ordinary hardback. It holds 10 novels within its covers, and comes, to my husband's relief, with an invisible bookshelf that knows no limits. It's an electronic book, also known as an e-book.

E-books are handheld devices that store text and graphics and display them on a built-in screen. But this is easier said than read. Until last November, with the introduction of NuvoMedia's Rocket eBook, the Millennium Reader from Librius, and the SoftBook from SoftBook Press, attempts to develop a viable electronic book had met with failure. This time around, however, two technologies helped pave the way

to success: the Internet, which provides a quick, easy way to deliver content; and perhaps more important, low-cost, easy-to-read displays.

With these new e-books, the Internet is your bookstore. When you buy an e-book, it's empty of content. So the first thing you do is go shopping—online. For the Rocket eBook and Millennium Reader, this means cabling a docking station to your computer, installing some communications software, and logging onto the Internet via computer. For SoftBook owners, no computer is necessary. You simply plug a phone line into the SoftBook's built-in modem and dial directly into the SoftBook Press server—connecting you to a vast electronic warehouse.

By Suzanne Kantra Kirschner

Diary of an Online Reader

An electronic book creates space—and peace—at home.

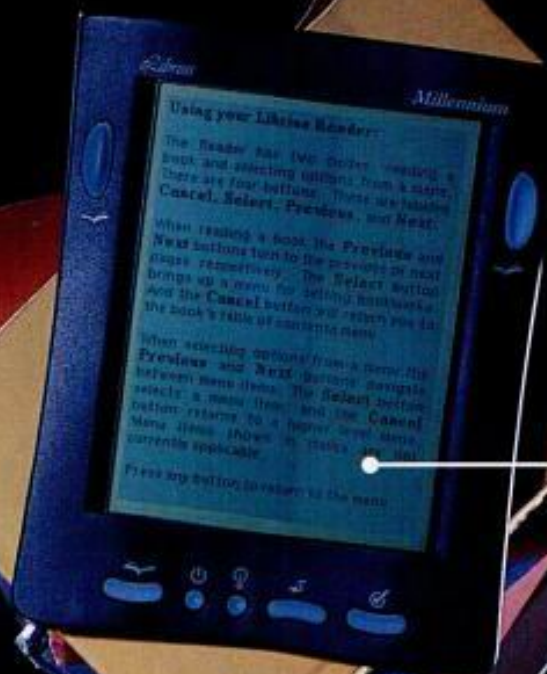
E-Book Extras

IT'S EASY to get used to the e-books' added benefits, such as one-handed reading and a backlight for dimly lit situations. Is a particular word stumping you? Just double-tap on it and a window opens with a definition, if you're using the SoftBook or Rocket eBook.



Millennium Reader

Turning a page with one hand is as easy as pressing a button.



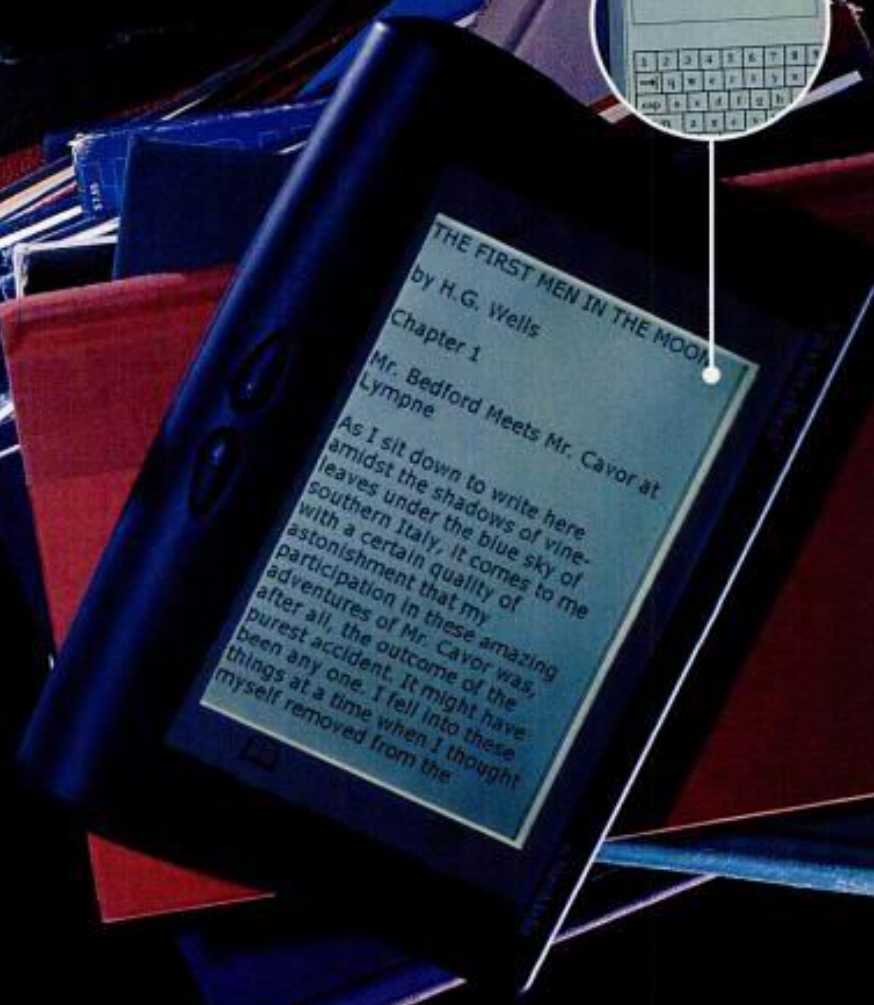
Rocket eBook

A pop-up onscreen keyboard enables you to take notes or search for keywords.



SoftBook

Scribble notes right on the page and you can save them to the SoftBook for future reference.



PHOTOGRAPHED BY JOHN B. CARNETT

Next, you hit the online bookstore. Rocket eBook content, which includes books, journals, and newspapers, is available online from bookstores and many publishing houses. The Millennium Reader and SoftBook limit you to material on their own sites.

Buying a title for your e-book is essentially the same for all three machines. As you browse, you simply hit the purchase button next to the titles you want. When you're ready to buy, click on the checkout button. You'll see the list of the titles you've selected, plus payment options. Verify this information, and download up to 4,000 pages worth of good reading. Pricing is comparable to what you'd pay at your favorite bookstore.

It took me a little while to become accustomed to reading novels on a screen, but once I adjusted, I came to love the added benefits. I could read with one hand, easily paging through a mystery by pressing a button with my thumb. And I didn't have to worry about marking my place. If left unattended, the e-book shuts itself off to conserve battery power but automatically returns to the page you last read. But the best feature is the backlit display. I found I could read in dimly lit taxis, and, more important, in bed after my husband was asleep.

The bells and whistles stop here for the paperback-book-size Millennium Reader. At \$199, it's the least expensive of the three e-books and, at 10 ounces, also the lightest. You do get what you

pay for in terms of the screen, however. The Millennium Reader's display is not nearly as good as the other two. Though perfectly adequate, the contrast between the text and background isn't as crisp onscreen as it is on paper, or even on a regular computer monitor.

Also the size of a paperback novel, though twice as heavy, the Rocket eBook is a major step up in quality and price (\$500). What you're paying for is the screen, an eye-soothing, high-contrast touchscreen that rivals the high-quality active-matrix displays used in notebook computers. It's the best of the three. Using the Rocket eBook's stylus, you can highlight or underline passages, and with its on-screen keyboard you can perform keyword searches and take notes.

MILLENNIUM READER

PRICE: \$199
BATTERY LIFE: 18 hours
WEIGHT: 10 ounces
SIZE: 6.3 by 4.5 by 0.6 in.
SCREEN SIZE: 4.75 by 3.6 in.
SPECIAL FEATURES: None

SOFTBOOK

PRICE: \$299, plus \$19.95 monthly subscription
BATTERY LIFE: 5 hours
WEIGHT: 46 ounces
SIZE: 8.5 by 11 by 1 in.
SCREEN SIZE: 6 by 8 in.
SPECIAL FEATURES: 33.6Kbps modem, touchscreen

ROCKET eBook

PRICE: \$500
BATTERY LIFE: 20 hours
WEIGHT: 20 ounces
SIZE: 5 by 7.5 by 1.5 in.
SCREEN SIZE: 4.5 by 3 in.
SPECIAL FEATURES: Touchscreen

The SoftBook is more than twice the size and weight of the other two. This is an advantage with journals and magazines, because you can read them at pretty much their original size.

The features are similar to those offered by the Rocket eBook except in one regard: With the SoftBook, you can scribble notes directly onto the screen and then save them in memory. The SoftBook's passive-matrix display doesn't quite measure up to the Rocket eBook's in terms of easy reading, but it's not hard on your eyes.

The SoftBook also costs less at \$299. However, there's a mandatory two-year \$19.95-per-month subscription, which covers the first \$19.95 worth of reading materials you buy per month—or nothing if you don't buy any titles in a given month.

Once you've bought a title, you own a copy even if you delete it. You can go back and download it again for free. With the Rocket eBook, the titles can be stored on your computer in a minimal amount of storage space. The makers of the Millennium Reader and SoftBook let you store books and other materials on a personal online bookshelf they maintain. The easy storage of electronic material brings one more benefit. Once an e-book version has been created, it costs next to nothing to keep it available. So the e-book may be the invention that keeps all books in print. ♦

Preventing E-Book Fraud

WHEN YOU BUY A TITLE, the e-book provides the store with an identifying code. The store uses that code to encrypt the title and sends it directly to the SoftBook, or via computer to the Millennium Reader or Rocket eBook.



Power Phones

What do you get when you merge a cellphone and a personal organizer? One pretty smart phone.

By Suzanne Kantra
Kirschner

QUALCOMM PDQ

PRICE	\$500 to \$1,000, depending on service
SIZE	6.2 by 2.6 by 1.4 inches
WEIGHT	10 ounces
SCREEN SIZE	1.9 by 2.4 inches



PHOTOGRAPHED BY JOHN B. CARNETT

ON A RAINY DAY in New York City, I can be 10 to 15 minutes late to an appointment without feeling too much guilt about not calling ahead. But sitting in a cab that's crawling along Park Avenue more slowly than I can walk, I finally had to concede I wouldn't make it to my destination within even my generous lateness guidelines. It was time to make the familiar "I'm running late" phone call, and check to see if the delay will have a domino effect on my schedule.

Ordinarily, that involves yanking two devices from my bag: my cellular phone (to make the call) and my personal organizer (to check my schedule and perhaps get the phone number I need). This time, however, I could do it all with one gizmo: my new smart phone, which combines a wireless phone with an electronic organizer à la 3Com's Palm or Franklin's Rex. It's the next best thing to having a human assistant at your side.

Smart phones aren't new, at least in concept. BellSouth merged cellular phone and handheld computer functions in its Simon, an innovative but bulky device that never caught on. Nokia's 9000, a phone that opened clamshell-style to reveal a keyboard and screen inside, was a considerably sleeker attempt to combine communication and organization, but it wasn't received very well either—at least in the United States—in part because it used the European GSM wireless

standard. (It got a warmer reception in Europe and even spawned a second generation, the Nokia 9110, last year.)

But even without a hit product, the idea makes too much sense simply to pass quietly into the conceptual mist. Now, two of the biggest names in cellular phones, Motorola and Qualcomm, are each taking a stab at wedding the engaged worlds of phone calls and personal info. Qualcomm's pdQ has an organizer built into the phone. Motorola's StarTac Mobile Organizer piggybacks atop a StarTac phone.

At first glance, the pdQ looks a bit like a mobile phone on

steroids. And at 10 ounces, it's about twice as heavy as some of the smaller wireless phones these days. But there's a lot going on inside. The keypad flips down to reveal a spacious (for a phone anyway) LCD screen, with icons that will be familiar to anyone who's used one of 3Com's Palm devices. Indeed, that's



MOTOROLA STARTAC MOBILE ORGANIZER

PRICE	\$250
SIZE	4.1 by 1.9 by 0.9 inches
WEIGHT	2.3 ounces (under 6 ounces with phone)
SCREEN SIZE	1.3 by 2.2 inches



what the pdQ is: a digital/analog wireless phone *and* a Palm III organizer in a package that, while large by cellphone standards, is smaller and lighter than the two combined.

As a CDMA protocol digital phone, the pdQ has all the latest perks, including voice mail, caller ID, and short-message service. All phone-related services are accessible via the dial pad. So you can make and receive calls, access your voice mail, and so on without ever digging into the organizer that literally lies beneath the surface. Flipping open the keypad activates the touchscreen and turns on all of the phone's Palm III capabilities. It can track your expenses, calendar information, addresses, and even phone numbers. It can also serve as a memo pad (complete with handwriting recognition) and a calculator. And, as with other Palm devices, it can synchronize all of this information with your desktop PC or Macintosh.

While the screen dimensions are the same as the Palm III's (160 by 240 pixels), the working area on the pdQ is smaller, in part because it displays phone-status information (signal strength, battery level, and roaming status) at the top. But in virtually every other way the hardware matches up, including 2MB of memory, a backlighting option, and integrated stylus for pointing or writing.

Conveniently, all of the Palm III functions can be accessed with the phone service turned off. (There's a phone icon on the side of the display that controls phone power in addition to a power button on the dial pad.) So you can peruse your contacts or appointments and save battery life when you're not expecting any calls, and even use the organizer functions on an airplane, where powering on the phone is forbidden. Yet there is some logical integration between its dual personalities. You can dial a phone

Downloading Data to Your Phone

MOST WIRELESS phones have built-in memory for storing 99 or more phone numbers. But using the phone's keypad to enter all of those names and numbers is a finger-numbing process that many people never get around to. FoneSync (\$80), by Paragon Software of San Jose, California,

lets you transfer this information to and from popular organizers, such as Lotus' Organizer, Microsoft's Outlook, and Symantec's Act, via an included serial cable. FoneSync is available for most mobile

phones, including models from Ericsson, Mitsubishi, Nokia, Panasonic, and Sony. Paragon can be reached at www.paragonsoftware.com.—S.K.K.



number from the address book, for example, and use the phone's communicating ability to send and receive e-mail (via your existing Internet account). You can even do some limited Web surfing with sites that support small-screen browsers.

The pdQ won't fit in your pocket, however, which is where the StarTac Mobile Organizer fits in. This 2.3-ounce device for any StarTac phone clips onto the spot otherwise reserved for an extended-life battery. Clipped together, the StarTac and Mobile Organizer still weigh less than 6 ounces. The pairing does double the size of the StarTac alone, but it's still pretty small.

Rather than opt for the popular Palm organizer, which requires a lot of screen space, Motorola chose to base the Mobile Organizer on the Rex, an organizer that's only slightly bigger than a credit card yet can synchronize

addresses, phone numbers, appointments, to-do lists, and memos with your desktop PC. This is a marriage that was clearly designed for use on the road. When clipped to the StarTac, the Mobile Organizer lets you dial numbers from the address book. But you can also download phone numbers from the organizer into the phone for times when you want to leave the organizer portion behind.

And the organizer can stand alone, since it draws power from its own batteries. This is especially handy when you're on the phone and would like to check your schedule. Instead of switching between talking and looking, as you would have to do with the pdQ, you can simply unclip the Mobile Organizer and operate it with your free hand. You can even customize the device for right- or left-hand use.

Some of the ounces that the Mobile Organizer eschews translate into limitations. You can enter information and edit entries on the Mobile Orga-

nizer, as you can on the pdQ. But the method for doing so—selecting one letter at a time with arrow buttons—is far too tedious and time-consuming for anything but quick appointment or phone number edits. E-mail, Web browsing, and expense tracking are lacking altogether, and you can't add new functions with third-party programs, as you can with the pdQ's Palm.

So in one corner you have the lightweight, the Mobile Organizer, and in the

other the heavyweight, the pdQ. But they won't be alone in battling for your briefcase. NeoPoint's 1000 is due sometime this fall, and Ericsson's R380 should be available early next year. This round, the cellular phone may have finally met its match. ♦



The NeoPoint 1000, like its pdQ competitor, will feature a big screen and have e-mailing capability.

Charting Your

By Ed Baig

I HAVEN'T THE foggiest idea what the longitude or latitude is in my neighborhood—or anyplace else, for that matter. So until recently, I didn't put much faith in Global Positioning System (GPS) devices that can calculate these and other navigational bearings. Sure, GPS serves a purpose. The two dozen orbiting satellites first launched by Uncle Sam two decades ago beam down radio signals to help keep earthlings on course, whether you're fishing for trout, hiking in the woods, or cruising along an unfamiliar country road.

Unfortunately, GPS receivers aimed at keeping ordinary consumers from getting lost have generally been too expensive or difficult to use. Handheld GPS receivers that don't display ordinary road maps were not very useful to longitude-challenged lugheads like myself.

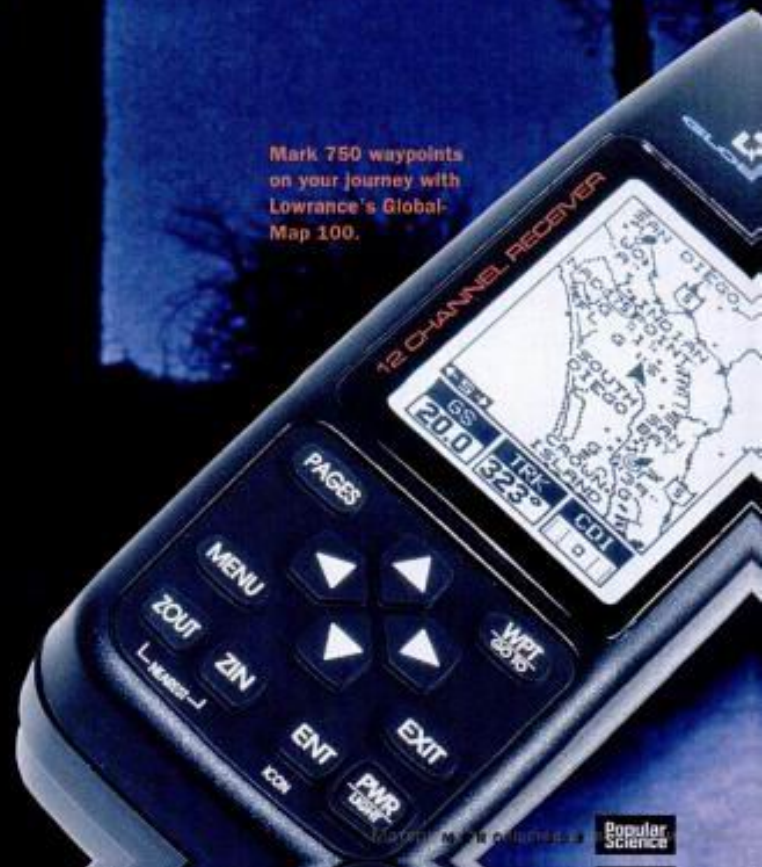
Worse, GPS models that were equipped with maps, typically dealer-installed in-vehicle navigation systems, tended to show up principally in luxury automobiles and pricey rent-a-cars. A cheaper, albeit more cumbersome, approach meant connecting a GPS receiver to a laptop computer. So I reckoned a paper map from Rand McNally was good enough for me.

Now I am rethinking my position. Several companies are offering a new breed of portable GPS receivers with maps to help you get where you're going and back. The devices may contain built-in base maps that can be enhanced with data memory cards or cartridges.

Magellan's \$350 Map 410 handheld GPS receiver, which is scheduled to be in stores this spring,



Want a GPS unit for more than one car? Garmin's StreetPilot can shuttle among them.



Mark 750 waypoints on your journey with Lowrance's Global-Map 100.

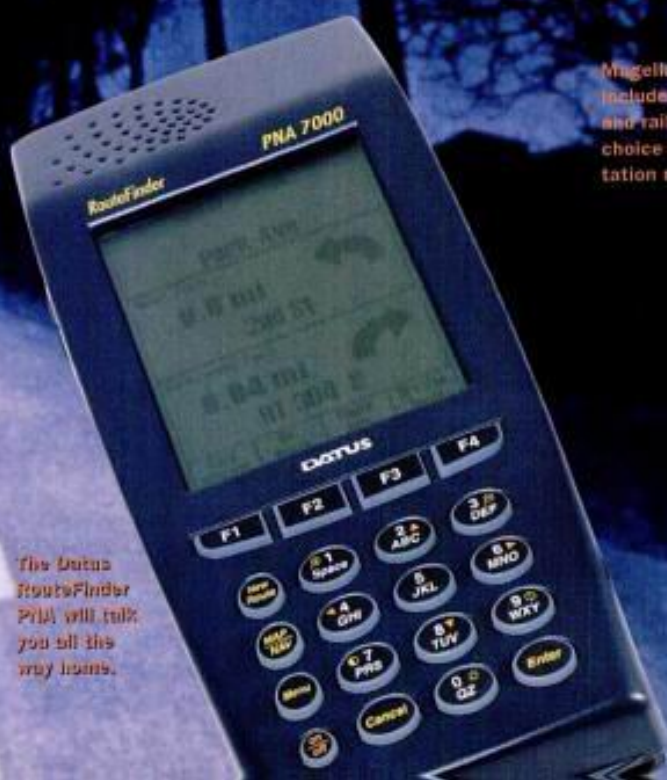
PHOTOGRAPHED BY JOHN B. CARNETT

Way Home

Forget longitude and latitude. New hand-held GPS devices are as easy to use as good old paper maps.



Magellan Map 410 includes both roads and railroads for a choice of transportation modes.



The Datus RouteFinder PNA will talk you all the way home.

will feature a base map that includes coastlines, cities, highways, and railroads—typical of these new products. If you purchase a \$100 MapSend CD-ROM, you'll also be able to upload marine charts onto the device, as well as information on campgrounds, tourist attractions, even ocean wrecks, which you can view on a 240- by 120-pixel display.

I recently examined three other portable GPS receivers capable of showing off maps: the StreetPilot I from Garmin, RouteFinder PNA from Datus, and the GlobalMap 100 from Lowrance Electronics. My testing ground was New York City, admittedly not the ideal locale for these devices. For one thing, to lock onto the satellites, GPS receivers must have an unobstructed view of the heavens, something that's nearly impossible in parts of Gotham. When I strolled by a skyscraper, the receivers temporarily lost reception.

As it is, GPS accuracy is not perfect. In the interest of national security, the Department of Defense intentionally degrades GPS signals for civilian use—and expects to continue doing so until 2005. So while GPS signals for the military are accurate to within 4 or 5 feet, consumer receivers are accurate within 100 meters, or 328 feet, of your position, 95 percent of the time.

The result? The units sometimes placed me a block or so from where I actually was. Each device that I tested uses 12 dedicated channels to lock on and continuously track as many as a dozen satellites. Only three are necessary to triangulate a position, so the chances of losing your connection are slimmer than

with older GPS models.

MAGELLAN MAP 410

COST \$350 **SIZE** 6.8 x 2.5 x 1.5 inches

COMMENTS An extra \$100 CD-ROM includes marine charts

GARMIN STREET-PILOT I

COST \$550
SIZE 3.2 x 6.8 x 2.2 inches

COMMENTS Mounts easily on dashboard

That may result in a quicker and more accurate reading.

I took to navigating the streets of New York by foot with the \$449 Lowrance GlobalMap 100, a handheld receiver that is designed primarily for outdoorsy types. From a distance, you might mistake the 12-ounce model for a cellular phone. Under the unit's backlit 160- by 104-pixel display are 12 keys for manipulating the images onscreen. The GlobalMap 100's antenna is hidden—you can connect an external antenna for better reception. Lowrance claims the device can work for as long as 20 continuous hours in a nonactive, PowerSave mode. When you first turn on the GlobalMap 100, a circular onscreen chart indicates the status of the satellites that are relevant to your position. Each time the receiver locks onto a signal to calculate location, the satellite is highlighted. Once the device determines your position, you can press various keys to alter your view of maps and navigational information. You can zoom in as close as one-tenth of a mile, or zoom out for a bird's-eye 2,000-mile view.

For even greater detail of a particular area, you can download up to 2 megabytes at a time from the included Inland Mapping System MapSelect CD-ROM. To handle the download, Lowrance supplies the cable that connects the Global Map 100 to the serial port of a computer. The CD-ROM houses a database of 64 different mapping regions for the 48 contiguous states, plus 39 maps from around the world. You can download the map you need when you're visiting an unfamiliar area, rather than having to purchase or rent cartridges. Inside the GlobalMap 100, you can save as many as 750 waypoints, or key locations, such as where you parked your car or pitched a tent. You can also set alarms to indicate when you are within a certain distance of a waypoint. En route, you can place tiny icons to mark, say, an area on a lake where the fish were biting.

While GlobalMap 100 is ideal for outdoor use, both Garmin's StreetPilot and the Datus RouteFinder PNA are designed for operation in a car. But unlike in-dash navigation systems, you can easily

move the devices from vehicle to vehicle—they weigh 1.2 and 2.0 pounds, respectively. The StreetPilot I tested costs \$550 with a 240- by 160-pixel, backlit grayscale display. After mounting StreetPilot on top of the dashboard, I flipped up a small, detachable antenna. The unit's base map covers the entire United States, but you'll have to purchase tiny MetroGuide data cartridges to display neighborhood cul-de-sacs and to access a database of museums, shops, and cash machines. The New York metro-area cartridge costs \$200. Smaller regions cost between \$100 and \$150. You can switch between a road sign page (directions,



plus distance and estimated arrival time information), dashboard page (odometer, trip computer data), or map page. The map scales from 200 feet to 800 miles.

I plugged in the New York data card, used power from a cigarette lighter adapter (in lieu of 6 AA batteries that Garmin says will last about 16 hours in power-saving mode), and searched the MetroGuide database for a specific Manhattan movie theater. The receiver mapped out a route to the theater and displayed the time I was likely to reach selected intersections along the way.

As I drove along, an arrow indicated when I had to make turns. Alas, on a few occasions, the arrow briefly pointed me the wrong way before correcting itself. In another curious twist, as I was cruising along the West Side of Manhattan, StreetPilot indicated that I was driving south near Guttenberg. From the perspective of the satellites, I suppose I was relatively near Guttenberg. The problem: Guttenberg is in New Jersey, separated from Manhattan by the Hudson River.

With StreetPilot, you have to consult the screen to get the next bit of driving instructions. That's not the case with the Datus RouteFinder PNA (PNA standing for portable navigation assistant). Instead, a grandmotherly voice reads turn-by-turn directions aloud. Having a loquacious navigator doesn't come cheap, however. RouteFinder, which is based on the Windows CE operating system, carries a misleading \$995 list price. Misleading because for the unit to operate, you must shell out an additional \$299, \$399, or \$599 for a 20-, 40-, or 85MB Navigation Technologies flash memory card. The size depends on how large a coverage area you require. These type III PC Cards fit into a slot at the bottom of the RouteFinder. At the top of the unit is a type II PC Card slot for connecting an optional wireless data modem or two-way pager. There is also an infrared port for communicating with a PC, but a Datus executive admitted you can't do much of anything useful with it yet.

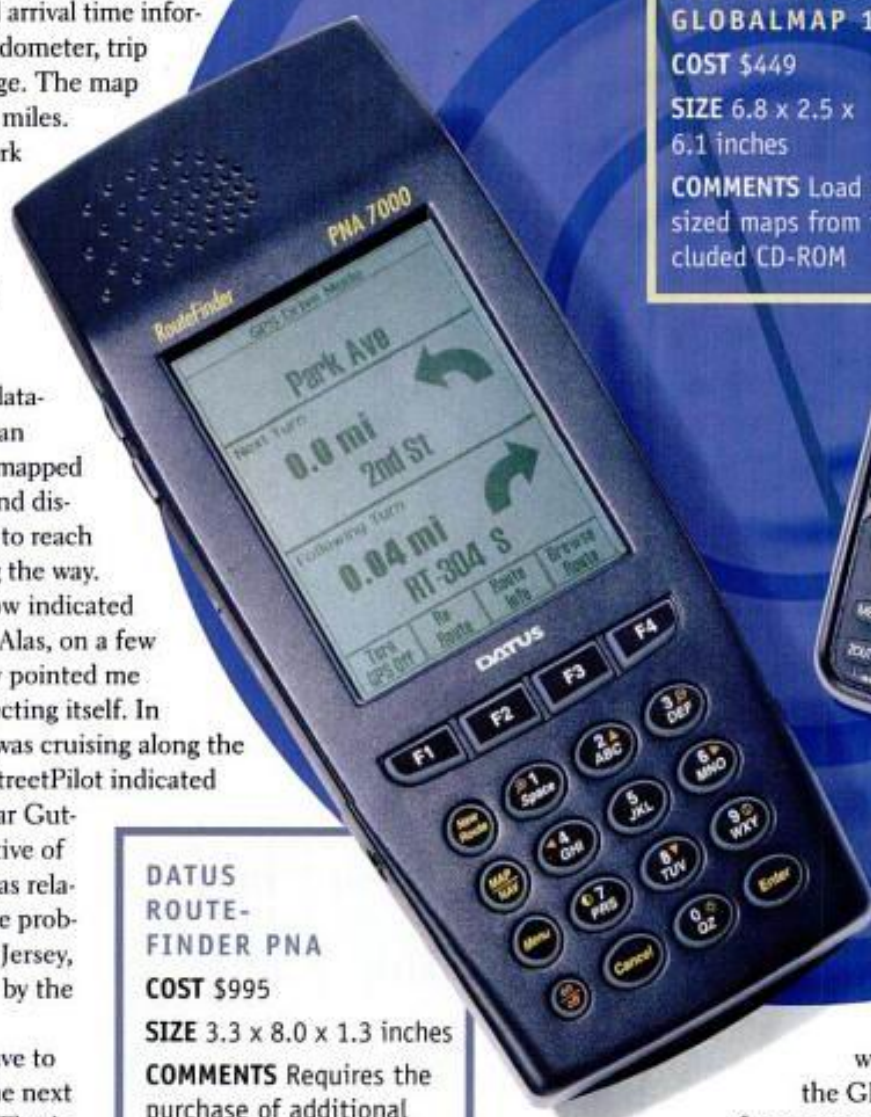
The 3.3- by 8.0- by 1.3-inch RouteFinder is a bit taller than the StreetPilot. Without the optional mounting kit, I was unable to position the device on top of my dash so I could view the 4.1-inch grayscale backlit LCD. With the voice instructions, of course, you won't need to eyeball the screen as much as with the Garmin model. I did have

LOWRANCE GLOBALMAP 100

COST \$449

SIZE 6.8 x 2.5 x 6.1 inches

COMMENTS Load 2MB-sized maps from included CD-ROM

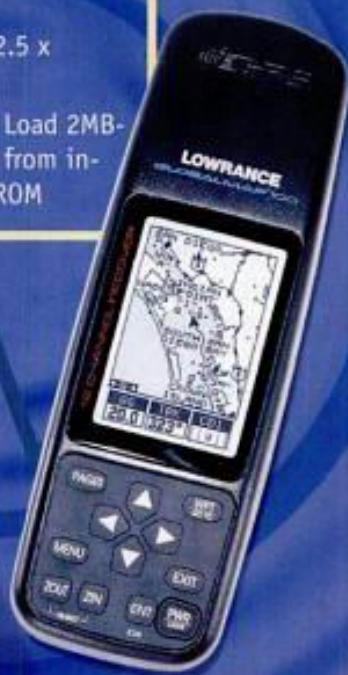


DATUS ROUTE- FINDER PNA

COST \$995

SIZE 3.3 x 8.0 x 1.3 inches

COMMENTS Requires the purchase of additional flash memory cards



to run a wire carrying the GPS antenna from a port on the upper right side of the PNA through

my car window. I then adhered the magnetic base carrying the antenna to the exterior metal of the car. As with Street Pilot, I connected a cigarette lighter adapter and went on my merry way.

RouteFinder calculates directions to specific addresses you enter via an alphanumeric telephone-type keypad. You can have the unit calculate the shortest or fastest routes, or a course that avoids major freeways. If you have trouble making out the voice in traffic as I sometimes did, you can look over maps and directions on the screen. The next two turns are always on display.

"Turn right ahead on St. Claire," said the voice as I took an exit ramp off the Henry Hudson Parkway. I appreciated the fact that such instructions came well in advance of the intersection. I was curious to see what would happen if I failed to follow the prescribed directions. "You appear to be off the route," came a polite warning when I took a wrong turn. The voice gave me the option to have RouteFinder recalculate the directions. Coming up with a new route took a few minutes, but once back on course, I was comforted by the fact that somebody above was looking out for me. ▶

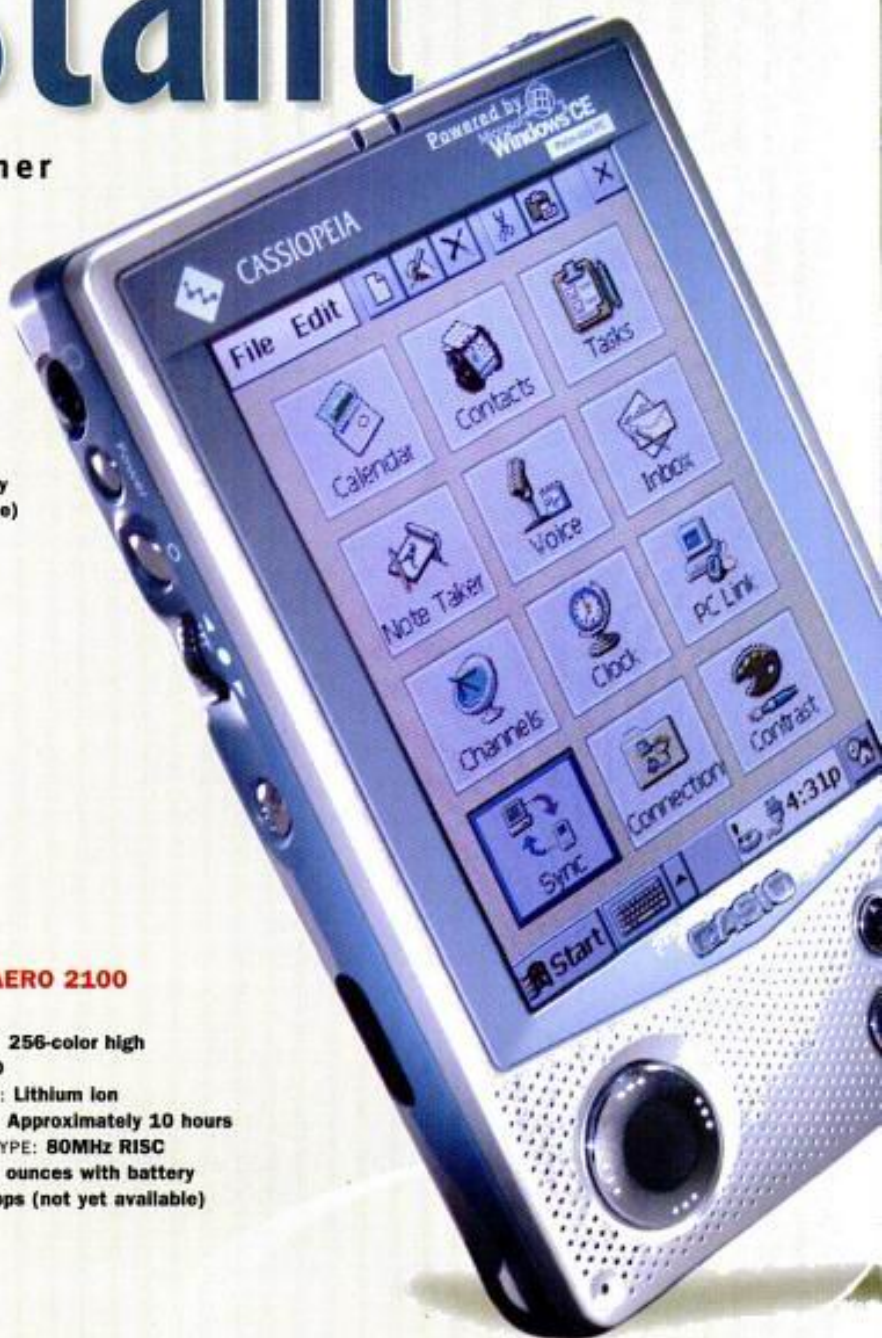
Your Brilliant Assistant

By Suzanne Kantra Kirschner

Now, palm-size computers deliver a rainbow of colors with high contrast that's easy on your eyes.

CASIO CASSIOPEIA E-100

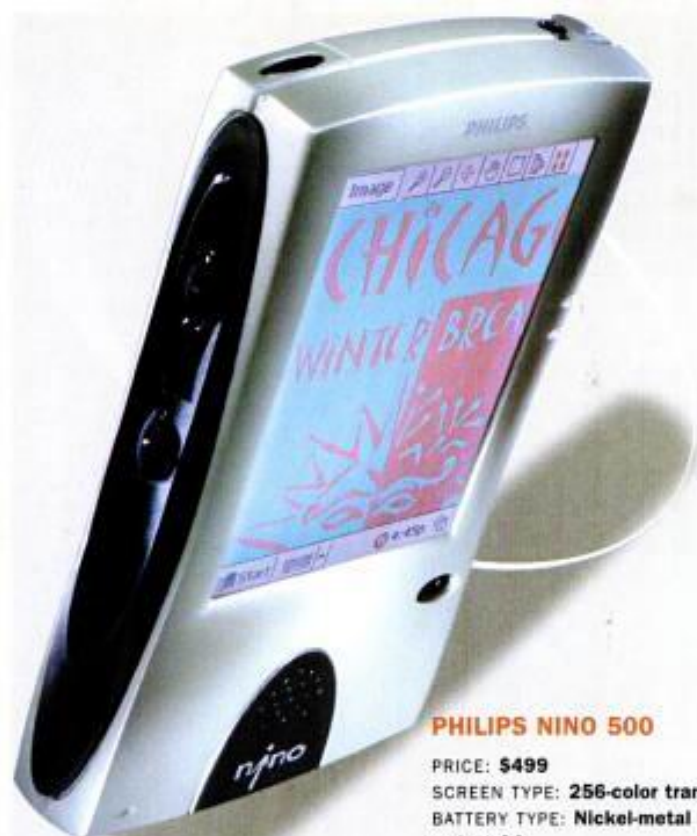
PRICE: \$499
SCREEN TYPE: 65,536-color active matrix LCD
BATTERY TYPE: Lithium Ion
BATTERY LIFE: Approximately 6 to 8 hours
PROCESSOR TYPE: 131MHz RISC
WEIGHT: 10.5 ounces with battery
MODEM: 56Kbps (not yet available)



COMPAQ AERO 2100

PRICE: \$499
SCREEN TYPE: 256-color high reflective LCD
BATTERY TYPE: Lithium Ion
BATTERY LIFE: Approximately 10 hours
PROCESSOR TYPE: 80MHz RISC
WEIGHT: 10.9 ounces with battery
MODEM: 56Kbps (not yet available)





PHILIPS NINO 500

PRICE: \$499
 SCREEN TYPE: 256-color transmissive LCD
 BATTERY TYPE: Nickel-metal hydride or two AA
 BATTERY LIFE: 8 hours
 PROCESSOR TYPE: 92MHz RISC
 WEIGHT: 8.0 ounces with battery
 MODEM: 14.4Kbps (\$90)



HEWLETT-PACKARD JORNADA 420

PRICE: \$519
 SCREEN TYPE: 256-color passive matrix display
 BATTERY TYPE: Lithium Ion
 BATTERY LIFE: 6 hours
 PROCESSOR: 100MHz RISC
 WEIGHT: 8.8 ounces with battery
 MODEM (THIRD PARTY): Pretec Electronics CompactModem, 56Kbps (\$170)

BLACK 7 ON GRAY 8. Gray jack on black queen. Playing solitaire on the screen of a handheld PC leaves something to be desired—namely, color. But until recently, color wasn't even an option on these pint-size PCs. Now, you have your pick of color handhelds with the introduction of Casio's Cassiopeia E-100, Compaq's Aero 2100, Hewlett-Packard's Jornada 420, and Philips' Nino 500, all based on the Windows CE platform.

OK, solitaire may not be the most productive example of color's appeal. Some of the perks are admittedly hard to quantify. But this much is certain: Color gives you a clearer view of what's on these tiny screens, and adds a comforting Windows feel (assuming you do Windows) to these Windows CE gadgets, with familiar icons that more vividly pop out at you. To the extent that your CE companion is a complement to your desktop or laptop, that puts your world a bit more in sync. And there are some concrete advantages to color too. You can view images attached to e-mail messages, for example, or do some limited Web browsing in color. (All come with browser software, though modems are optional.)

When you get right down to it, though, most of your time is spent peering into the screens of these palmy assistants, trying to read appointment schedules or phone numbers. And that's where the benefit of color comes into stark relief—literally. The grayscale displays used on previous models simply don't have the contrast that the color displays have. So while the resolution of the text may be the same, it's easier to read on the color displays because you're seeing black text on a white background rather than dark gray text on a light grayish-green background. Palm Pilot maker 3Com Corp. recognizes the problem too, and while its latest product, the Palm V, still has a monochrome display, the contrast is vastly improved (see "What About a Color Palm?").

What price color? Aside from the

PHOTOGRAPHED BY JOHN B. CARNETT

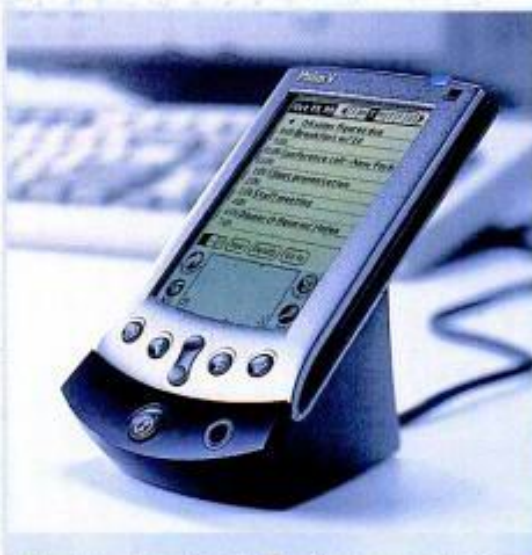
What About a Color Palm?

PALM PILOT OWNERS can be forgiven for a little color envy. While many of the Windows CE handhelds are adding color displays, the Palm remains stubbornly monochrome. Future Palm products may have color displays, says 3Com, but the company won't say exactly when. Industry rumor has it that a color model, code-named Raptor, might be out as early as the end of this year.

In the meantime, 3Com is not resting on its well-earned laurels. The most recent additions to the Palm family, the Palm V and Palm VII (the company decided to skip the even numbers), have higher-resolution displays with better contrast, and address a few key battery life and communications problems.

With the Palm V (\$449), you may never have to worry about changing or charging your battery again. Its built-in lithium ion battery will run for 30 days without needing a recharge. But

It may be monochrome, but the Palm V is slimmer than its color counterparts.



you need not even think about recharging if you keep the Palm V in its synchronization cradle, which has a battery charger built in. Every time you swap data with your desktop PC, the battery is topped off. The Palm V is also nearly half the thickness, at 0.45 inches, and a full 2 ounces lighter than the Palm III, which weighs 6 ounces. The Palm V nonetheless retains all of the Palm III capabilities. It has the same 2MB of storage, wireless infrared transmitter, and software as the Palm III, which includes an expense tracker, games, e-mail, address book, and calendar.

The Palm VII (less than \$800) also has the Palm III's features, but adds a built-in two-way radio for wireless access to e-mail. You can forward messages from your current e-mail account while you're on the road, or people can send messages directly to your Palm VII account. And you can send e-mail to any Internet e-mail address. To retrieve messages, you just raise the antenna and the unit downloads them from the nationwide wireless radio network. Such freedom brings a monthly service charge, of course, which starts at \$10.—S.K.K.

\$500 purchase price of these gadgets, you'll pay for a superior screen with abbreviated battery life. These devices last for a mere 6 to 10 hours of continuous use on a charge (or in the case of the Nino, on a pair of alkalines). Compare that with the 30 days you'll get with a Palm V.

As laptop PC users know, not all color screens are created equal. Each of these palm-size PCs uses a different screen technology. The Cassiopeia's active matrix (or TFT) LCD is by far the best display. This technology, the same used in better laptops, is the brightest, and it displays thousands of colors rather than the hundreds the others do. The extra colors translate into more accurate skin tones and finer color gradations in pictures. The Casio has a standard CompactFlash slot for adding more memory or a modem but offers few extra programs or perks.

Aero's 256-color reflective active matrix LCD uses ambient light to generate color rather than powering

each pixel to glow as the Cassiopeia does. It offers a crisp display under bright lights, but lacks color clarity in low-light conditions even with its front light turned on. It still packs lots of useful goodies, however. It has a shielded CompactFlash slot so it can also accept pager cards without the threat of RF interference, plus a vibration alarm for appointment reminders. A robust software bundle includes a program for playing audio content downloaded from the Web, a flight scheduler, an image file viewer, and an English to Spanish or Japanese dictionary.

The passive matrix LCDs of the Nino and Jornada are not quite as bright as the Cassiopeia's screen, but they're actually brighter than the Aero's reflective display. Passive displays, used in some low-cost laptops, distribute light by row, rather than the active-panel approach of delivering it to each pixel. This method of back lighting saves power, and the Nino is the only color model that can run on

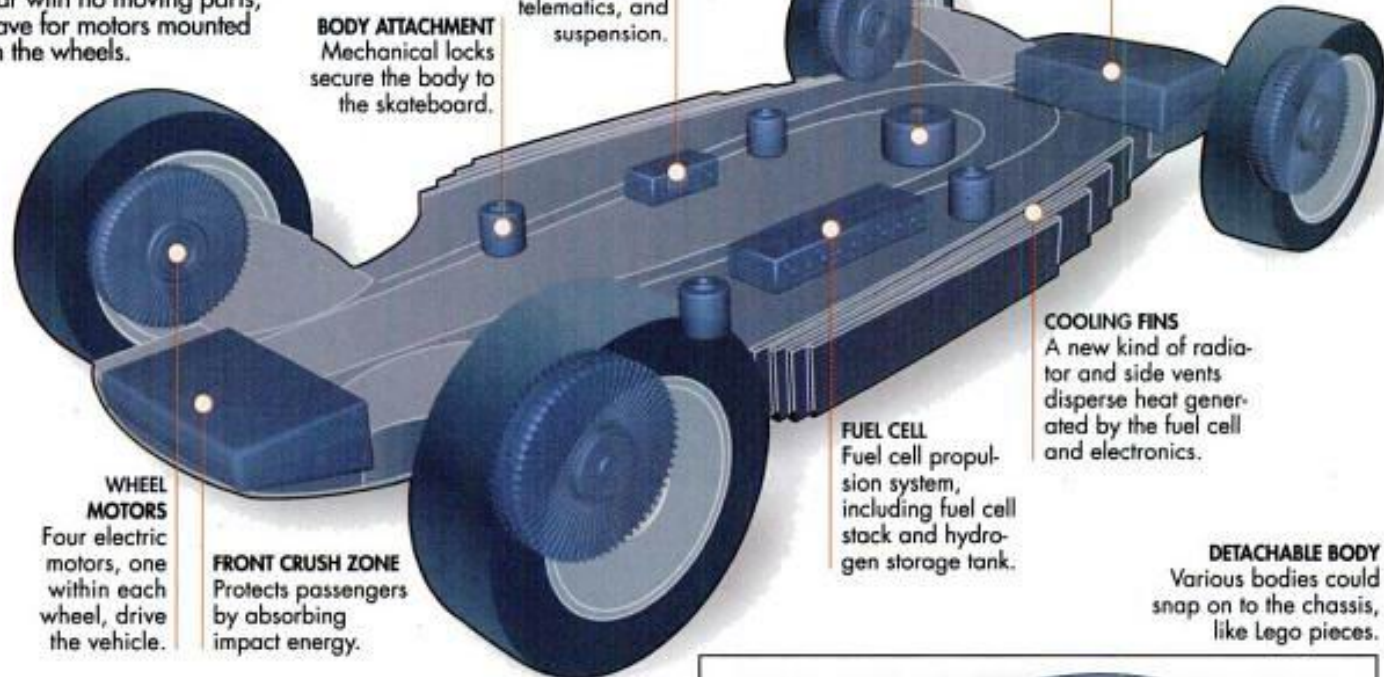
rechargeable or alkaline batteries. The Nino and Jornada are about 2 ounces lighter than the active matrix models too, which is more noticeable than it may sound in pocket-size devices. Both also come with audio player and image viewer software, as well as a CompactFlash slot (with the Jornada's being shielded for pager cards). The Jornada has another nice touch: a transparent cover, which folds back when you're using the device.

What's notably absent from all of these palm-size PCs is a built-in modem. Philips, Casio, and Compaq will offer modems as an option. Third parties already sell modem cards and will soon have pager cards as well.

Why pay the premium for a colorized companion? Better visibility is certainly the main reason, and that's no small matter in a gadget you depend on to organize your life. But color is at least as much visceral as it is functional here. Still, if it gets you to the meeting on time, it might just color your world a happier place. ♦

How the Autonomy Works

Electronic precision triumphs over mechanical power to create the first car with no moving parts, save for motors mounted in the wheels.



CONTROL CENTER

The vehicle's computerized brain, coordinating the by-wire functions, telematics, and suspension.

BODY ATTACHMENT

Mechanical locks secure the body to the skateboard.

WHEEL MOTORS

Four electric motors, one within each wheel, drive the vehicle.

FRONT CRUSH ZONE

Protects passengers by absorbing impact energy.

FUEL CELL

Fuel cell propulsion system, including fuel cell stack and hydrogen storage tank.

COOLING FINS

A new kind of radiator and side vents disperse heat generated by the fuel cell and electronics.

UNIVERSAL DOCKING CONNECTION

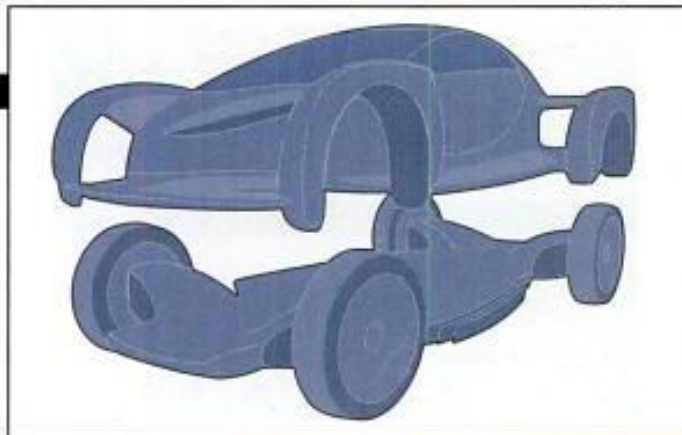
Communications port that connects the driver-controlled systems—steering, braking, power, and climate—with the skateboard.

REAR CRUSH ZONE

Protects passengers by absorbing impact energy.

DETACHABLE BODY

Various bodies could snap on to the chassis, like Lego pieces.



designers retire, they quite possibly could see the last of the internal combustion engine," says Ed Golden, executive director of Ford's North American design operations. "They will probably create vehicles that are more significant and different than anything current designers like me will do in our careers."

What makes the Autonomy approach so intriguing is that it would allow drivers to own several car bodies for just one skateboard, then alter the layout and look of their vehicles according to the dictates of lifestyle or mood. (A reality that would also transform the marketplace: Would a GM skateboard accept only GM bodies, or also third-party hardware? GM envisions the skateboard forming the platform not just for a few car models, but for dozens of models globally, changing the economics of production.) Each body would snap on to the Autonomy base, and its interior technology—controls, power, heating, and cooling—would connect to the chassis through a docking port on the platform. A family might own a commuter sedan body and a sport or SUV body for weekends or vacations, then buy a specially configured body so that, for example, a newly disabled family member could roll a wheelchair directly into the driving position. A notion like this has implications for another great American institution, the two-car garage—or perhaps the bodies would be stored at depots for quick installation. Within a given car body there would also be flexibility: Passenger and even driver seat positions could be moved; a car could be turned into a mobile office, even a mobile bedroom. Some of this seems fanciful, but when you clear the decks above the skateboard, the possibilities are astounding.

Before unveiling the Autonomy, GM held an internal con-

test to see what kinds of attachable auto bodies its designers could come up with. We decided to take a similar route, asking two independent design firms to brainstorm new configurations for the car of the future, based on the Autonomy concept. We encouraged the firms not only to play with interior configurations, but to fundamentally alter the architecture of the automobile, creating vehicles that are not only innovative but functional. Prisma Design International of Tustin, California, responded with a novel SUV and adjustable-bed pickup; Aria-Group of Irvine, California, conceived a snap-on sports car and a sedan.

Designers are buzzing about the potential versatility of the Autonomy—especially when it comes to interiors. "The task of driving is different at different points in the day or in one's life," says Jaron Rothkop, a senior industrial designer at Lear Corp., an automotive interiors supplier. The Autonomy yields a car that can evolve to a much more profound degree than aftermarket add-ons have ever made possible.

Drive-by-wire technology, meanwhile, would enable the steering wheel to become an aircraft-type control yoke or a

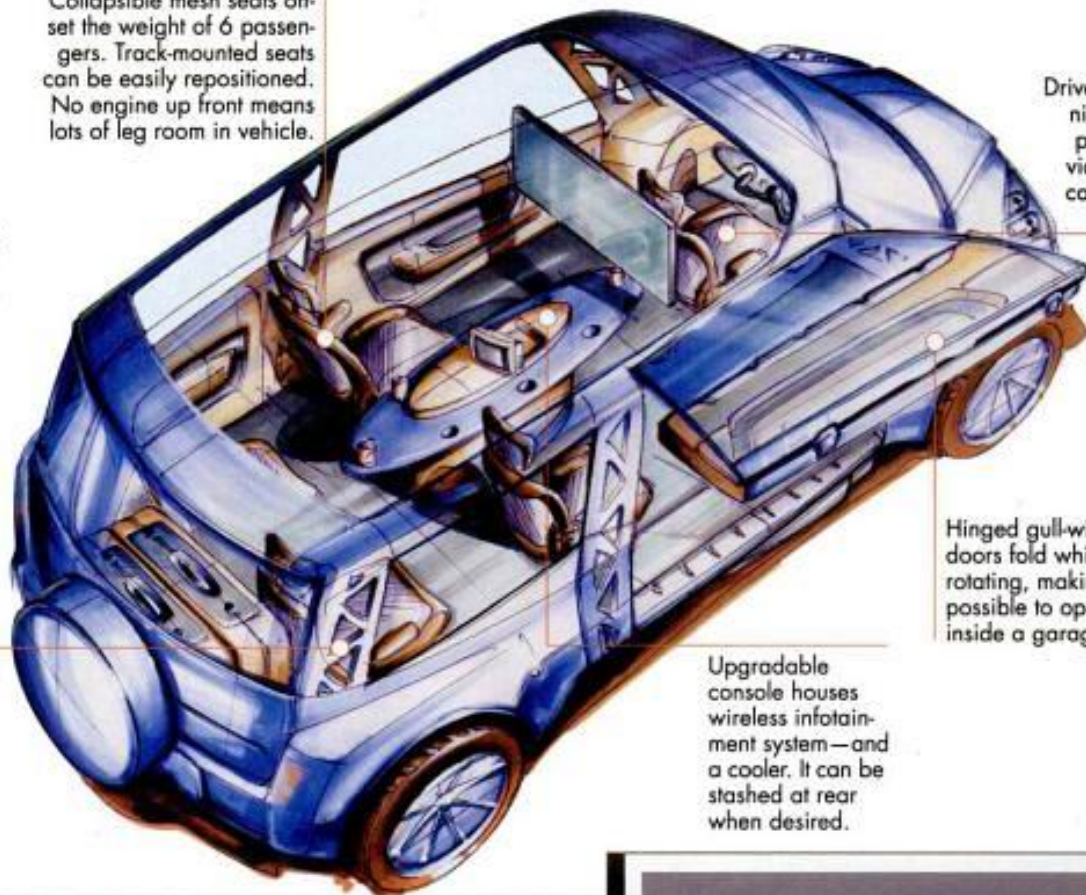
DESIGNER/PRISMA DESIGN
CATEGORY/SUV

Sport Utilitarian

The SUV has evolved into the most functional automobile around, a minivan with sex appeal. Without the constraints of a bulky engine compartment or a transmission that creates a hump in the floor, designers at Tustin, California-based Prisma Design increased the size of the passenger compartment and used the Autonomy's 42-volt power supply to run a bevy of onboard electronic equipment.

Collapsible mesh seats offset the weight of 6 passengers. Track-mounted seats can be easily repositioned. No engine up front means lots of leg room in vehicle.

Cross-hatched vertical pillars reduce weight and increase visibility.



Driver communicates with passengers via two-way camera and intercom.

Hinged gull-wing doors fold while rotating, making it possible to open them inside a garage.

Upgradable console houses wireless infotainment system—and a cooler. It can be stashed at rear when desired.

joystick, if that were desired by some drivers. Whatever the device, it would not need to be attached to a conventional steering column and could, potentially, be docked in several places about the car. John Phillips, director of industrial design and advanced product development at Lear, suggests it could be pulled down from the ceiling when required and hidden away (a security plus) when the car was stationary and doubling as a living or working space. When traveling alone, the driver could sit in the center of the vehicle, for increased safety in case of a collision; side- or rear-view cameras would provide a full range of vision. A British motorist who drove frequently to France on business could shift his position from right to left and back again. The absence of an engine compartment, meanwhile, could make cars safer, with new room for crash-absorbing material in front of the driver.

There is work to be done, of course, before the skateboard is ready for prime time. That work starts with the fuel cell. Fuel cells have come a long way since 1994, when Daimler-Benz unveiled a van whose fuel cell stacks and hydrogen tanks were so large they consumed the majority of the space inside. Ford, BMW, Volkswagen, Honda, and most of the other big carmakers either have experimental fuel cell vehicles on the road, or will have them there soon. But no fuel-storage system as compact as that required by the skateboard is in view; if the skateboard is 6



ROOM TO EXPAND

Prisma's early sketches (see above) seized upon the Autonomy's extra room, squeezing a third row of seats into a Civic-sized vehicle.

To view more sketches from Prisma Design, check out www.popsci.com/exclusive

SOMETHING TO BUILD ON

The sports car is a snap-on on top of a snap-on. Not only are most of the car's components removable (below, an early sketch with canopy but without trunk), the entire body is as well.



inches thick, the tanks will have to be mere inches high. Liquid hydrogen requires thick, insulated tanks that can maintain the fuel at 253° C below zero. Compressed hydrogen requires even more bulky, highly stressed tanks. One alternative is to store hydrogen in a solid medium, a kind of metal sponge, with the fuel chemically bonded to the metal and released when warmed by waste heat from the fuel cells. Chemical storage would be the safest approach, but current metal sponges cannot hold enough hydrogen to fulfill a vehicle's energy needs.

"The fuel cell group within General Motors is comfortable with the Autonomy's skateboard concept," says Chris Borroni-Bird, who is in charge of design and technology fusion at GM and led development of the Autonomy. "We're looking at four or five approaches to hydrogen storage. We don't want to close the door on any approach."

Drive-by-wire technology might seem less of a hurdle than the fuel cell challenge. Fly-by-wire is standard in big jets, and in cars, limited by-wire systems—controlling throttle, suspension settings, and some braking equipment—can be found already in BMW's new 7 Series, the Mercedes SL500, the latest GM pickups, and the Chevrolet Corvette. But the Autonomy strategy is vastly more ambitious, a full-system, by-wire network of computers and electronic motors that would require redundancy systems to prevent, say, a full system failure in the event of electrical outage.

POPSCI DESIGN CHALLENGE

DESIGNER/ARIA-GROUP
CATEGORY/TWO-SEATER

Snap-On Sports Car

Removable body panels allow the driver to modify the roadster to his own needs: attached for extra storage, detached to minimize weight.

A true sports car needs little more than an engine, wheels, and a driver. Conveniences add comfort, but at the cost of weight and reduced responsiveness. The designers at Aria-Group in Irvine, California, imagined an Autonomy-based bolt-on roadster, with removable body panels in lieu of a permanent hood, roof, sides, or trunk.



Optional trunk turns the roadster into a car suitable for a weekend vacation.

Full Frontal Sedan

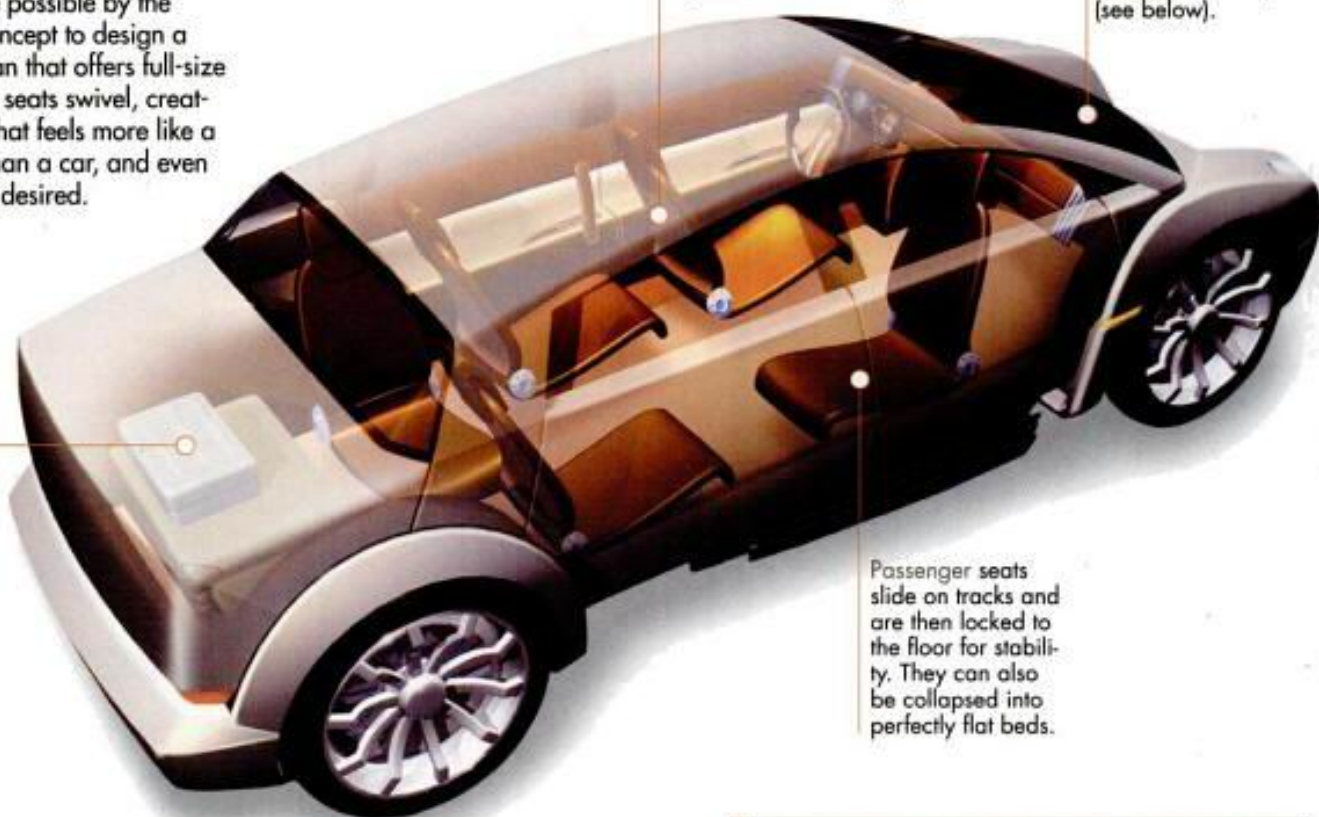
Aria-Group used the large interior volume made possible by the Autonomy concept to design a mid-size sedan that offers full-size legroom: The seats swivel, creating a space that feels more like a small room than a car, and even lay flat when desired.

Driver's seat is positioned high, for better visibility.

Front window reaches down to the bumper (see below).

Trunk panel extends to the bumper, creating a larger opening for easy loading.

Passenger seats slide on tracks and are then locked to the floor for stability. They can also be collapsed into perfectly flat beds.



Back-up solutions include secondary batteries, multiple computer systems, and independent brake systems for each wheel. But for a universal, global platform like the Autonomy, all this needs to be accomplished at less-than-Mercedes—let alone less-than-Airbus—prices.

There are other problems relating to fit. The electric wheel motors, for example, will be integrated into the wheel hubs. They have to be powerful enough to provide 15 to 20 kilowatts of force, yet small and lightweight enough that the suspension system can keep the wheels firmly in touch with the road as they pass over bumps. Another obstacle: fabricating auto bodies that are structurally sound, won't come apart or off during a collision, yet can be easily snapped on to the skateboard.

The engineers have a lot to do, but designers are simply having fun with the skateboard's potential. Prisma Design International, one of the two firms hired by POPULAR SCIENCE, has imagined a pickup truck in which the driver's seat swivels 180 degrees while the steering wheel is unplugged and repositioned, so the driver can look *forward* when steering a load through a tight spot *in reverse*. The truck design also features a bed and cab that can compress while the other expands; essentially, an adjustable cab-to-bed ratio in one vehicle. Prisma also designed an SUV that takes advantage of the sheer volume that results from pushing the engine to the bottom; it includes an entertain-



PERSONAL PORTAL

Freed from the need for a view-blocking engine and steering column, the designers lowered the windshield to the bumper (see sketch above), opening new vistas to car occupants.

To view more sketches from Aria-Group, check out www.popsci.com/exclusive

REMOTE CONTROL DRIVING

With drive-by-wire technology, the car can be operated via remote control. Below, the driver fine-tunes his parking from the sidewalk.



ment console/cooler/table that slides to the rear when not needed. The windshield of the sedan designed by Aria-Group extends practically to the vehicle's bumper level—a neat trick made possible by the absence of an engine compartment. The seats fold down into beds that lie flat on the car's driveshaft-free floor. In Aria's go-kart-like sports car, pop-off storage containers in the front, where the engine would normally be, give a two-seater the trunk capacity of a sedan (at 15 feet, it is about the length of an old Jaguar E-Type: Imagine the carrying capacity).

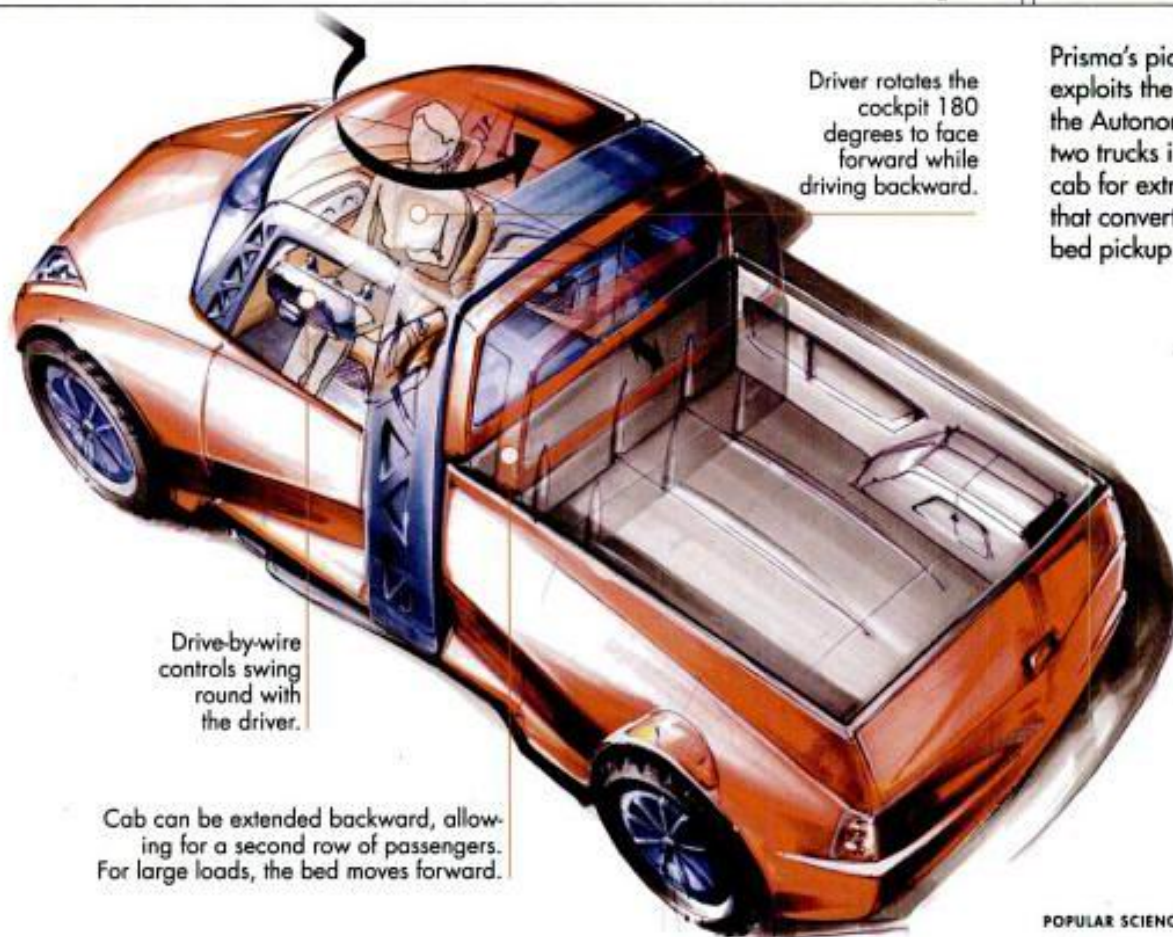
Predicting the future of the car has always been a dangerous business. In addition to the lounge car from 1940—not entirely unlike Prisma's SUV, by the way—classic covers of this magazine included a car that moved on spheres instead of wheels, a car on skis, and a two-wheeled car on giant hoops. The difference now is that major technological advances are at hand. When cars are free of the engines and many of the mechanical systems that govern their current configuration, that configuration will inevitably fall away, as happened with the first horseless buggies. The Autonomy may die, but the idea behind it will not: If technology proceeds as it should, the car in 20 years will surely be very different from your father's Oldsmobile. ■

Find more classic POPSCI car covers at www.popsci.com/exclusive

POPSCI DESIGN CHALLENGE

DESIGNER/PRISMA DESIGN
CATEGORY/TRUCK

Two-Faced Pickup



Driver rotates the cockpit 180 degrees to face forward while driving backward.

Drive-by-wire controls swing round with the driver.

Cab can be extended backward, allowing for a second row of passengers. For large loads, the bed moves forward.

Prisma's pickup design exploits the flat profile of the Autonomy to produce two trucks in one: a king cab for extra passengers that converts into a long-bed pickup when needed.